State of California
The Resources Agency
Department of Water Resources
Northern District

# ANTELOPE GROUND WATER STUDY

April 1987

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Secretary for Resources
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## FOREWORD

Tehama County officials have long been concerned about the quality of the ground water in the Antelope area just east of Red Bluff. Over the years, analysis of water samples has shown bacterial counts, and in some cases nitrate concentrations, to be unacceptably high.

The Antelope area obtains its water from domestic wells and small, private water systems and disposes of its waste through individual septic systems.

The County needed a more complete knowledge of the area's ground water resources and their quality to evaluate any ground water pollution threat to public health. In January 1985, the County and the Department of Water Resources entered into a cooperative agreement to study the area's geology, ground water hydrology, and ground water quality so the County can make recommendations for future water development and waste water management.

This report presents the results of the study, including recommendations that will improve the current ground water quality monitoring program.

Wayne Gentry

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Special thanks to Ken Peters, Katie Knight, and the members of the drill crews of Heitman Drilling Company, who kept us informed of drilling schedules for the last year and allowed us to sample drill cuttings throughout the study area.

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# CONVERSION FACTORS

| Quantity | To Convert from Metric Unit | To Customary Unit | Multiply Metric Unit By | To Convert to Metric Unit Multiply Customary Unit By |
|---|---|---|---|---|
| Length | millimetres (mm) | inches (in) | 0.03937 | 25.4 |
| | centimetres (cm) for snow depth | inches (in) | 0.3937 | 2.54 |
| | metres (m) | feet (ft) | 3.2808 | 0.3048 |
| | kilometres (km) | miles (mi) | 0.62139 | 1.6093 |
| Area | square millimetres ($mm^2$) | square inches ($in^2$) | 0.00155 | 645.16 |
| | square metres ($m^2$) | square feet ($ft^2$) | 10.764 | 0.092903 |
| | hectares (ha) | acres (ac) | 2.4710 | 0.40469 |
| | square kilometres ($km^2$) | square miles ($mi^2$) | 0.3861 | 2.590 |
| Volume | litres (L) | gallons (gal) | 0.26417 | 3.7854 |
| | megalitres | million gallons ($10^6$ gal) | 0.26417 | 3.7854 |
| | cubic metres ($m^3$) | cubic feet ($ft^3$) | 35.315 | 0.028317 |
| | cubic metres ($m^3$) | cubic yards ($yd^3$) | 1.308 | 0.76455 |
| | cubic dekametres ($dam^3$) | acre-feet (ac-ft) | 0.8107 | 1.2335 |
| Flow | cubic metres per second ($m^3/s$) | cubic feet per second ($ft^3/s$) | 35.315 | 0.028317 |
| | litres per minute (L/min) | gallons per minute (gal/min) | 0.26417 | 3.7854 |
| | litres per day (L/day) | gallons per day (gal/day) | 0.26417 | 3.7854 |
| | megalitres per day (ML/day) | million gallons per day (mgd) | 0.26417 | 3.7854 |
| | cubic dekametres per day ($dam^3$/day) | acre-feet per day (ac-ft/day) | 0.8107 | 1.2335 |
| Mass | kilograms (kg) | pounds (lb) | 2.2046 | 0.45359 |
| | megagrams (Mg) | tons (short, 2,000 lb) | 1.1023 | 0.90718 |
| Velocity | metres per second (m/s) | feet per second (ft/s) | 3.2808 | 0.3048 |
| Power | kilowatts (kW) | horsepower (hp) | 1.3405 | 0.746 |
| Pressure | kilopascals (kPa) | pounds per square inch (psi) | 0.14505 | 6.8948 |
| | kilopascals (kPa) | feet head of water | 0.33456 | 2.989 |
| Specific Capacity | litres per minute per metre drawdown | gallons per minute per foot drawdown | 0.08052 | 12.419 |
| Concentration | milligrams per litre (mg/L) | parts per million (ppm) | 1.0 | 1.0 |
| Electrical Conductivity | microsiemens per centimetre (uS/cm) | micromhos per centimetre | 1.0 | 1.0 |
| Temperature | degrees Celsius (°C) | degrees Fahrenheit (°F) | (1.8 × °C)+32 | (°F−32)/1.8 |

# CHAPTER 1. INTRODUCTION

Field work on a two-year investigation of the Antelope area geology, ground water hydrology, and ground water quality started in May 1985 by the Department of Water Resources (DWR), Northern District. Funding was provided by the State of California and Tehama County under the terms of a cooperative agreement. The County Division of Environmental Health provided field assistance and laboratory services for bacterial analyses.

## Area of Investigation

The study area is on the east side of the Sacramento River in the northern part of the Sacramento Valley. The Antelope study area includes Antelope, an unincorporated area, and that portion of the city of Red Bluff east of the Sacramento River. Antelope, Red Bluff, and the study area are shown on Figure 1.

Land use in the Antelope area is 15 percent residential and commercial, 55 percent orchard and row crop, and 30 percent undeveloped or dryland grazing. State Route 99E runs east and west through the area and serves as a corridor for urban business and some light industry. Part of this corridor is connected to the Red Bluff municipal water and sewer systems. There are 23 privately owned community water systems within the 12-square-mile study area, but most residences have domestic wells and individual septic tanks. Orchard and row crops are irrigated by large-capacity wells or surface water. There is at least one pump diversion from the Sacramento River and a gravity diversion from Antelope Creek.

The area has hot, dry summers and mild winters. Summers are long with cloudless, sunny days from May through October. Temperatures are highest during July and August, often exceeding 100 degrees F.

Precipitation, mostly rain, occurs during winter and spring as Pacific storms cross the area. Average annual precipitation at Red Bluff is about 23 inches.

## Purpose

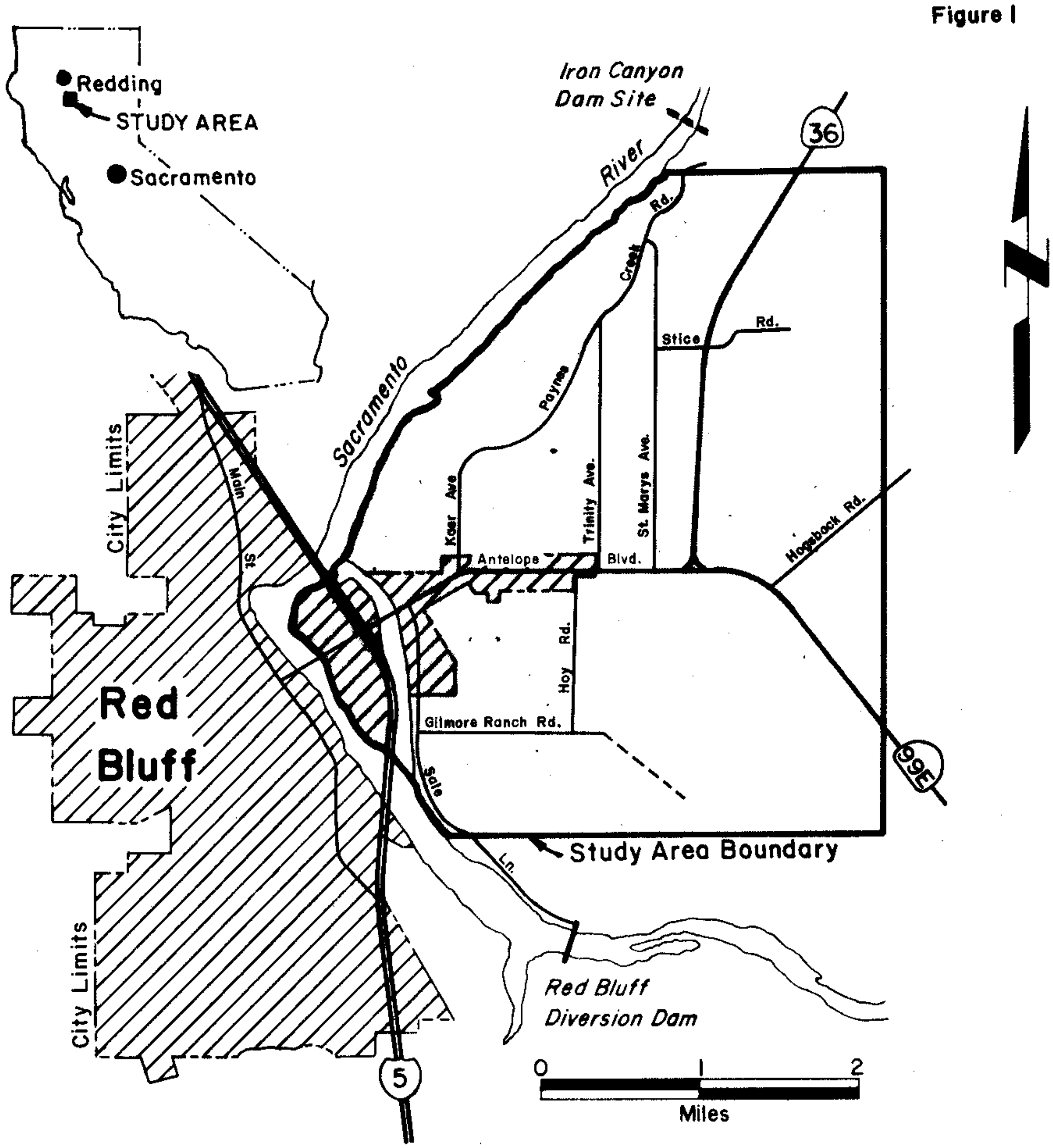
The purpose of this report is to describe the geologic and hydrologic characteristics of the water-bearing materials in the Antelope area, develop information on the depth to ground water at various times of the year, determine gradients and direction of ground water movement, and evaluate water quality problems found during sampling.

During the course of the investigation, DWR:

1. Collected and evaluated available geologic, hydrologic, and water quality data.

2. Located 87 water wells in the field and documented their data.

Figure I




Antelope Ground Water Study
Location Map
1986

3. Compiled a geologic map and cross sections using water well drillers reports, Department of Transportation bridge data, and DWR and U. S. Bureau of Reclamation dam exploration data.

4. Measured water levels in 73 wells and prepared spring and fall ground water depth and elevation maps.

5. Collected water samples from 75 wells and analyzed them for mineral constituents. Mineral analyses included chloride, nitrate, phosphate, boron, and electrical conductivity.

6. Delineated areas of poor water quality.

## Scope and Methods

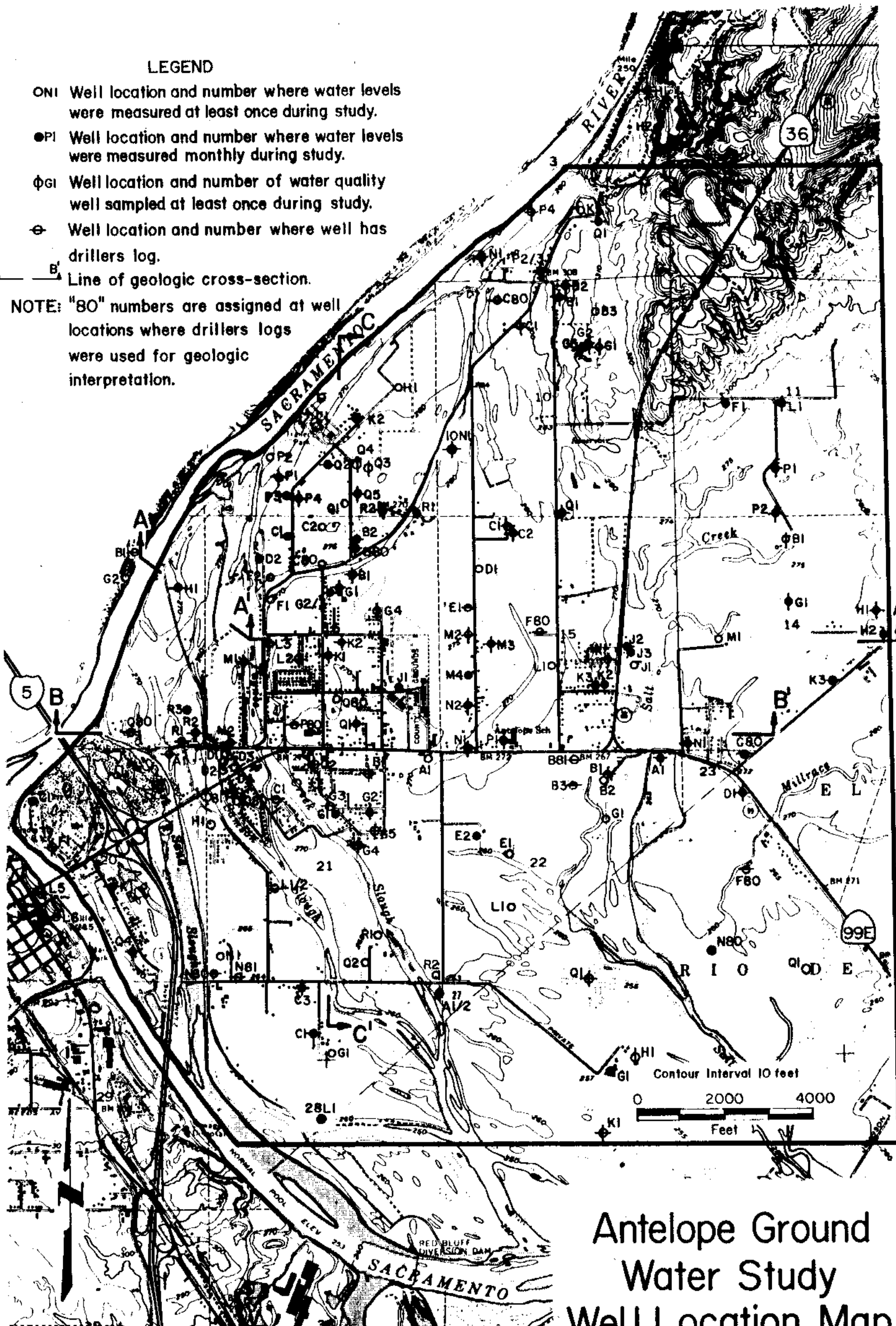
For many years, DWR has seasonally monitored selected wells in the Sacramento Valley, including some wells in the study area. The existing DWR Sacramento Valley ground water monitoring grid was reviewed and upgraded. This was done by selecting water well drillers reports from DWR files that had good lithologic and location descriptions. Each well was visited and the owner interviewed to ensure that the well data were accurate. Finally, each well was documented and an official State well number assigned (see Figure 2 for well locations). From this data base, water level and water quality monitoring grids were developed.

Water level measurements began in June 1985. Stevens continuous water-level recorders were installed on two wells. By June 1986, 40 wells were being measured monthly, and hydrographs were made from these measurements. Water levels were measured in about 80 wells in the spring and fall, and water-level contour and seasonal water-level change maps were constructed from these measurements.

The water quality grid for this study was first sampled in 1985. Temperature, pH, and electrical conductivity (EC) measurements were made at the time of field collection. Selected samples were then sent to the DWR chemical laboratory at Bryte for standard mineral analysis. After the mineral analyses were plotted on a map and contoured, new wells were located to help further define areas of poor quality ground water. In addition, 20 wells were sampled for bacteria, and Tehama County had the samples analyzed at the Shasta County Health Department laboratory in Redding for total and fecal coliform.

In August 1986, the area's aquifer system was defined and, along with the qualified wells, was used to help determine water quality patterns found during sampling.

Figure 2




# Antelope Ground Water Study Well Location Map

## Previous Studies

Geologic data came from numerous sources. The areal geology is modified from the U. S. Geological Survey's (USGS) "Red Bluff 1:100,000 Quadrangle" (1984). The distribution of the Tehama and Tuscan Formations near the study area is from previous studies by the U. S. Bureau of Reclamation (USBR), USGS, and DWR. Descriptions of these formations are based largely on the work of Anderson (1933) and Lydon (1967, 1968). The USGS has recently published a number of maps showing structural folds and faults (1981, 1982, 1985) and surface geology (1984) in the study area.

The first comprehensive ground water investigation that included the Antelope area was made by the USGS from 1912 to 1914. Results were published as USGS Water Supply Paper 495 in 1923. Other significant reports are "The Sacramento River Basin", State Division of Water Resources, 1931; USGS Water Supply Paper 1497, 1961; and DWR Bulletin 118-6, 1978.

Two damsite investigations contain specific hydrogeologic information about the Antelope area: the Red Bluff Diversion Dam Study (USBR, 1953) and the Iron Canyon Dam Investigation (DWR, 1960, and U. S. Army Corps of Engineers [USCE], 1947). These studies included drilling, coring, and geologic interpretations both north and south of the Antelope study area. USBR also studied the influence of Sacramento River and Lake Red Bluff seepage on the free ground water table in the western part of the study area. USBR installed a grid of piezometers and has measured water levels in 8 to 12 wells near the Sacramento River from 1962 (before completion of Red Bluff Diversion Dam in 1966) to present.

In 1970 and 1983, Tehama County conducted two unpublished water quality surveys of the area, in addition to its regular monitoring of public water systems. These two surveys led to the present joint ground water investigation. The County also applied for pollution study funding provided by the Clean Water Bond Law of 1984 and entered into a contract with Charpier, Martin, and Associates (CM&A) of Sacramento to study part of the Antelope area in detail. The County's purpose is to document the existence of ground water contamination or public health hazard in four sections adjacent to Antelope Boulevard. On June 19, 1986, CM&A wrote a preliminary report summarizing the survey data. In December 1986, CM&A sampled 28 wells in the area and provided DWR with preliminary results.

# CHAPTER 2. SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

## Summary

In May 1985, the Department of Water Resources started the two-year Antelope Ground Water Study, in cooperation with Tehama County. The purpose of this investigation was to describe the geologic and hydrologic characteristics of the water-bearing materials and delineate poor ground water quality so that recommendations for future water development and waste water management could be made.

### Hydrogeology

The Antelope area is in the northern part of the Great Valley Geomorphic Province, bounded by part of the Coast Ranges Province on the west and the Cascade Range on the east. Surface rocks in the area are Recent and Older Alluvium underlain by about 2,000 feet of interfingering Pliocene Tuscan Formation and Plio-Pleistocene Tehama Formation.

The main aquifers are in these two formations, which contain fresh water to a depth of 1,500 feet. The Recent and Older Alluvium also yield some water and are considered minor aquifers. The fanglomerate, Red Bluff Formation, Recent floodplain, and stream channel deposits are not considered water-producing units. Wells in the Antelope area are perforated in aquifers in the Tuscan and Tehama Formations, but generally are not perforated in Recent or Older Alluvium.

Analysis of water levels indicates that in some areas the Tuscan and Tehama Formations are partially confined, but in most areas they are unconfined and recharge can take place freely through overlying formations. Free ground water is recharged by precipitation, infiltration of applied irrigation water, percolation of domestic wastes, and the Sacramento River and Salt Creek.

Flow in the Sacramento River at Red Bluff is controlled nearly year-round by operation of Lake Shasta, Keswick Afterbay Reservoir, and Red Bluff Diversion Dam. Operation of the diversion dam, beginning in 1966, caused ground water levels to immediately rise near the river, demonstrating that much of the Older Alluvium is hydrologically connected to the Sacramento River.

A water level change map showing the change in ground water elevation between spring 1962 and spring 1986 shows a 5-foot to 10-foot increase in ground water levels over much of the southern portion of the study area during that time. The spring 1986 ground water elevation map shows that ground water elevations in Antelope are very near the elevation of the water surface of Lake Red Bluff (253 feet). The direction of ground water flow shows that the Sacramento River and Salt Creek recharge the ground water system. The fall 1986 ground water elevation map shows that water levels are locally drawn down 10 to 15 feet annually below the spring elevations and recover each year. This indicates recharge continues to come from both the river and Salt Creek.

## Water Quality

Quality of ground water in the Antelope area is generally good, with a median electrical conductivity (EC) of 450 micromhos per centimeter (μmho/cm) and total dissolved solids (TDS) of 296 milligrams per liter (mg/L). The median alkalinity expressed as calcium carbonate is 134 mg/L.

Lower quality in two parts of the Antelope area has limited beneficial uses of ground water. Nitrate levels are high in the west-central portion, and boron and chloride are high in the eastern portion. Historical data also suggest that bacterial contamination may be a problem throughout the study area.

Data collected during this study confirmed the presence of high nitrate concentrations in the west-central portion of the study area, north and west of State Highway 36 between Kaer and Trinity Avenues. In this area, several wells produced water containing nitrate concentrations exceeding 45 mg/L, and most other wells produced water with concentrations exceeding 20 mg/L.

There are numerous sources of nitrogen within the study area that could have contributed to the nitrates found in the ground water. The largest sources are probably domestic wastes from on-site sewage disposal systems, decomposing organic matter, fertilizers, and fixation of atmospheric nitrogen. The wells producing water containing the highest concentrations of nitrates are all in residential areas or adjacent to domestic sewage disposal systems that serve a number of people. Past and current fertilizer applications in upgradient ground water areas may have also contributed nitrates to the ground water.

High concentrations of boron are found in the ground water along the eastern portion of the study area, underlying Salt Creek and Little Salt Creek. Ground water in this area contains higher concentrations of chloride and total dissolved solids than does ground water in other parts of the study area. Also, it has higher adjusted sodium adsorption ratios, which indicate potential problems if the ground water is used for irrigation. Farmers have been aware of this poor quality water for many years, and have avoided boron- and salt-sensitive crops and have used care in their irrigation practices.

The boron and other dissolved solids that have impaired the ground water in this area probably come from the Cretaceous marine rocks, which are exposed higher in the watershed, and from water that flows from Tuscan Spring and Salt Creek Spring.

In June 1986, samples were obtained from 20 wells throughout the Antelope area and tested for coliform bacteria. Analysis of June samples provides data following the spring ground water recharge period, when contamination is most likely. Only two samples contained bacteria, indicating no widespread bacterial contamination of ground water in the study area.

Few wells were available for sampling the very shallow ground water, and some bacterial contamination might be occurring there, particularly in the residential area, where density of sewage disposal systems is high and nitrate levels would be expected to be elevated. A more detailed study now being conducted for the County should provide information on contamination of these shallow waters.

## Conclusions

This study of ground water in the Antelope area led to the following conclusions:

- Major aquifers in the Antelope area are in the Tuscan and Tehama Formations. These formations are generally overlain by about 40 feet of very permeable Older and Recent Alluvium. The aquifer systems appear to be "leaky", which allows surficial water to mix with deeper aquifers.

- Ground water recharge is from precipitation, infiltration of applied irrigation waste water, percolation of domestic wastes, the Sacramento River, and Salt Creek.

- Seepage of water from Lake Red Bluff has raised ground water levels 5 to 10 feet in much of the southern Antelope area since 1966, when the diversion dam gates were first closed.

- Nitrate concentrations in much of the Antelope area east of the Sacramento River floodplain are between 20 and 45 mg/L. These are not naturally occurring levels, but probably result from agricultural practices and domestic waste disposal systems. The nitrate problem areas north of Antelope Boulevard are in dense residential areas and appear to be related to individual sewage disposal systems. These areas are defined laterally, but not vertically.

- Generally, unconfined ground water occurs where the Older or Recent Alluvium is underlain by thick impervious zones in the Tuscan and Tehama Formations. It appears that septic effluent may be trapped here and eventually percolate into aquifers of the deeper Tuscan and Tehama Formations. Nitrate concentrations are lower west of Paynes Creek Slough, probably because of dilution. There the Older or Recent Alluvium is up to 70 or 80 feet thick.

- The lack of adequate surface seals on wells probably contributes to the flow of nitrates into the ground water. In areas of high nitrates, it may be necessary to construct wells with deeper surface seals to prevent the intake of nitrates.

- The area affected by nitrates in ground water from individual sewage systems (septic tanks and leach lines) may become greater as development continues.

- There is enough good quality water in the area to meet present water demands.

## Recommendations

This study has resulted in the following recommendations. The County should:

- Continue to enforce Tehama County Water Well Ordinance 1308 for construction of new wells and destruction of abandoned wells. In the Antelope study area, the minimum for surface seals on domestic wells should be changed from 20 feet to 50 feet.

- Require an analysis of water from new wells to ensure the water meets State-recommended limits for EC and nitrate. Samples for analysis should be taken when first water is encountered and again at well completion.

- Establish a grid of monitoring wells in the high nitrate area to monitor changes in water quality and water levels.

- Require that all property exchanges involving domestic water wells include a recent (less than one-year-old) water analysis for EC and nitrate.

- Determine the feasibility of expanding the public water and/or sewer system into the Antelope area.

## CHAPTER 3. REGIONAL GEOLOGY

California may be divided into natural geomorphic provinces according to certain characteristics -- relief, landforms, and geology -- that distinguish each province. These distinctive characteristics have been developed through natural geologic processes acting on the rocks and structures over many millions of years.

The Antelope area is in the northern part of the Great Valley Geomorphic Province (Figure 3). The province is bounded on the east by the Cascade Range Province and on the west by the Coast Ranges Province. Since the early Cretaceous period (150 million years ago), the area that is now the Great Valley has been receiving sediments from the surrounding highlands. Evidence indicates that it is now being slowly uplifted (Helley and Jaworowski, 1985).

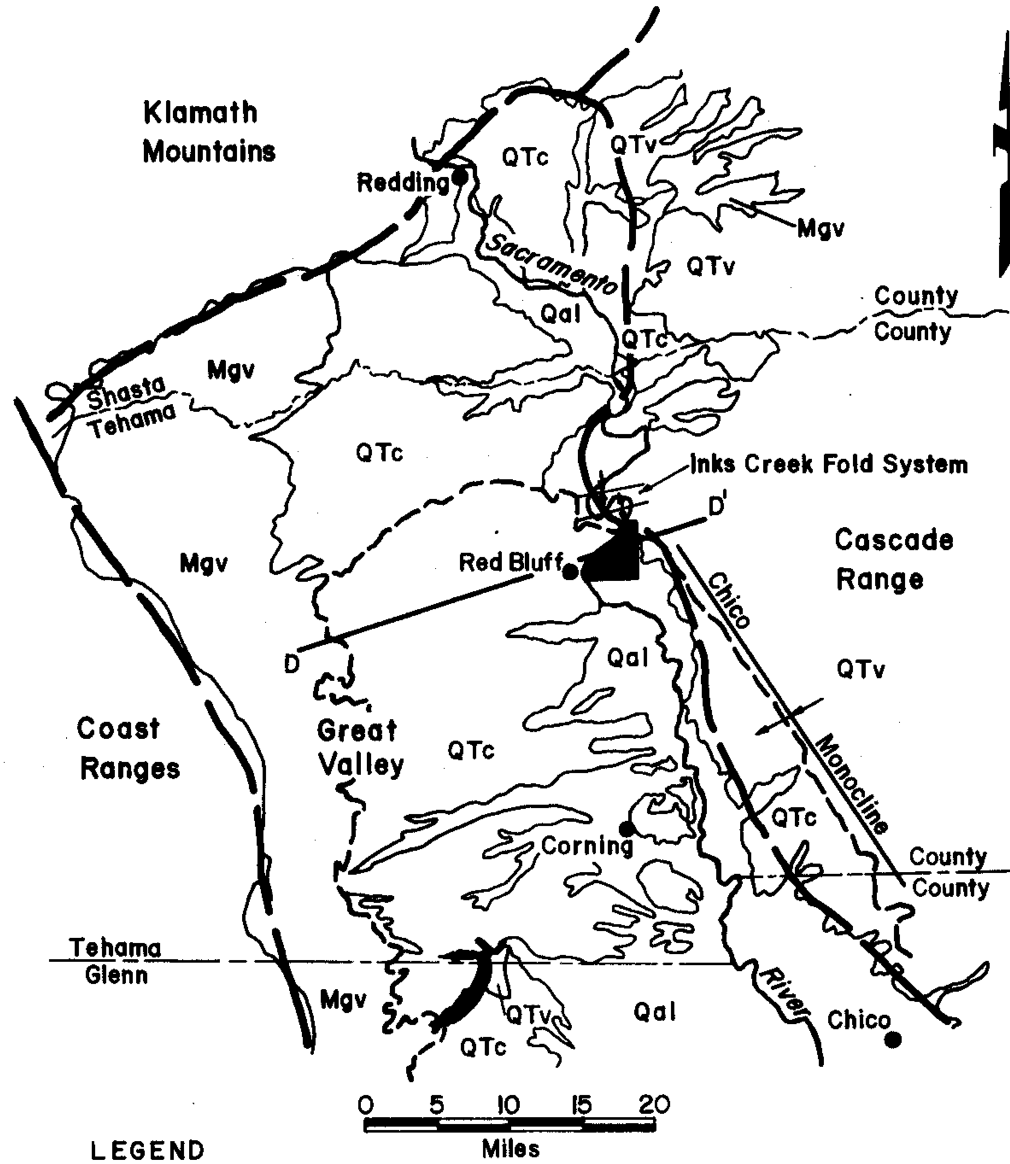
The Great Valley Province is a large elongate structural trough that contains a thick sequence of predominantly sedimentary rocks ranging in age from Jurassic to Recent. During the Mesozoic era, this trough was part of the continental shelf and ocean floor on which the Cretaceous marine Great Valley Sequence was deposited. By early Pliocene, after uplift of the Coast Ranges, the present boundaries of the Great Valley were well developed and deposition changed to mostly continental. The Great Valley Sequence rocks are exposed along the western edge of the Sacramento Valley.

Since Pliocene time, the Cascade Range Province has contributed volcanic mudflows, tuff, and tuff breccia intermixed with stream-lain volcanic sand and gravel (Tuscan Formation). The Coast Ranges Province on the west side of the valley and the Klamath Mountains Province on the north have contributed predominantly sand and gravel with subordinate clay and silt derived from igneous and metamorphic rocks (Tehama Formation). The Tuscan Formation grades westerly into predominantly volcanic sand, silt, and clay where it is interfingered with the Tehama Formation beneath the valley. The Antelope study area is underlain by 1,500 to 2,000 feet of Tuscan and Tehama deposits (Figure 4).

The Tehama and Tuscan Formations were eroded and leveled following their deposition during the early Pleistocene. During this period, the Red Bluff Formation and the fanglomerate were deposited in the north valley area. At the end of the Pleistocene, the area was elevated and incised. The Sacramento River removed Red Bluff Formation deposits east of the river, along with some of the fanglomerate. The river appears to have migrated from east to west across the Antelope area. As it shifted its course across this floodplain, it backfilled, leaving the older alluvial deposits. These gravels become successively younger to the west where they border the active Sacramento River alluvium.

Recent alluvium now fills the Sacramento River channel, and floodplain deposits consisting of sand and silt overlie the Older Alluvium on the floodplain in the Antelope area.

Figure 3




LEGEND

Qal Recent sedimentary deposits.

QTc Cenozoic Great Valley sedimentary deposits.

QTv Cenozoic Cascade Range volcanic rocks and deposits.

Mgv Mesozoic Great Valley sequence rocks.

Approximate Geomorphic Province Boundary.

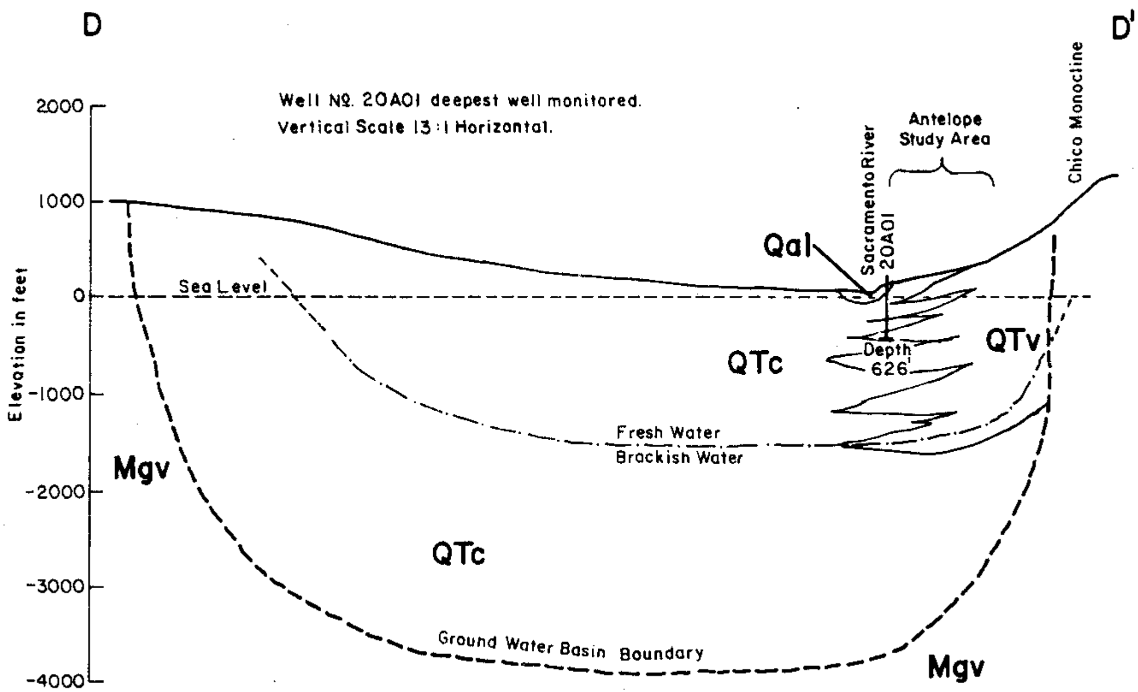
Sacramento Valley Ground Water Basin Boundary.

Antelope Study Area.

D—D' Geologic Diagrammatic Section.

## Regional Geology of the Northern Sacramento Valley

Figure 4




# Northeast-Southwest Diagrammatic Section D-D'
# Northern Sacramento Valley Ground Water Basin

The northern Sacramento Valley ground water basin has geologic boundaries. For purposes of this study, the Great Valley Sequence rocks discussed above form the western boundary and the bottom of the basin. The remaining sides are formed by the Chico Monocline and the Inks Creek fold system.

The Chico Monocline is a late Cenozoic fold, bordering the east side of the valley between Chico and Red Bluff. East of the monocline, the Tuscan Formation dips less than 5 degrees. West of the monocline, bedding steepens to 20 degrees or more at the edge of the valley, then dips beneath Quaternary deposits. Folding and faulting of the monocline was in response to a deep-seated fault (USGS, 1981). This fault system and the folding and faulting to the north at Tuscan Springs could serve as conduits for the migration of poor quality connate waters. Great Valley Sequence rocks exposed at Tuscan Springs yield highly mineralized thermal water.

The Inks Creek fold system is a series of northeast-trending folds north of the Antelope area. It caused the major loops in the Sacramento River between Red Bluff and Redding, and it isolates the Redding ground water basin from the Sacramento Valley ground water basin.

Structural contour maps of the Sacramento Valley by the USGS (Harwood and Helley, 1982) delineated geologic folds and faults in the subsurface near Antelope. The axis of the Los Molinos syncline trends northwest toward the central part of the Antelope area, and the Red Bluff fault strikes northeast across the northeastern edge of the Antelope study area. However, no positive evidence of either feature was found in the area. It is also unlikely that these features would affect the hydrologic character of sediments in the upper 500 feet.

# CHAPTER 4. GEOLOGY

The Antelope area is underlain by the Tuscan and Tehama Formations. These deposits are locally overlain by the Red Bluff Formation and fanglomerate along State Route 36 near the northern edge of the study area. In the valley portion of the study area, undifferentiated Older Alluvium, Recent Alluvium, stream channel, and floodplain deposits mantle the Tuscan and Tehama deposits (Figure 5).

Geologic units descriptions in the following section are based on the present study, on the USGS preliminary geologic map of the Red Bluff 1:100,000 metric scale quadrangle (Blake and others, 1984), on USCE's Iron Canyon Dam Investigation (1947), and on USBR's Red Bluff Diversion Dam Study (1953). Table 1 shows the stratigraphic sequence of geologic units in the Antelope area.

## Tuscan Formation

The Pliocene Tuscan Formation is composed of volcanic breccia, tuff, tuff breccia, volcanic sandstone and conglomerate, basalt flows, and tuffaceous silt and clay. The volcanic rocks are predominantly andesitic and basaltic. The Formation is a tabular mass that tilts southwesterly from the Cascades. From a maximum thickness of 1,700 feet in the Cascade Range (Lydon, 1968), the formation thins southwesterly to about 1,500 feet beneath the study area, where it interfingers with the Tehama Formation.

The best exposures of the Tuscan Formation are along the Sacramento River upstream from the study area and in the surrounding foothills north and east of the area. Three members of the Tuscan Formation that were defined along the Sacramento River and probably underlie the study area were delineated and are, from oldest to youngest: the Seven-Mile tuff and sand, the Iron Canyon agglomerate, and the Sacramento tuff and sand.

The Seven-Mile tuff and sand member crops out along the canyon of the Sacramento River upstream from Iron Canyon Dam site. The member consists predominantly of tuffaceous volcanic sand and conglomerate, with tuff and at least two thin lapilli-agglomerate interbeds. Thin layers of fine-grained clayey to silty tuff separate tuffaceous volcanic sand beds.

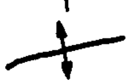
The Iron Canyon agglomerate consists of subangular blocks up to 10 feet in diameter of andesitic and basaltic rocks in a coarse, sandy tuff matrix. The blocks are generally surrounded by matrix. The entire member is dark gray. Thickness in Iron Canyon is about 70 to 150 feet, thinning south where it pinches out under the Sacramento Valley.

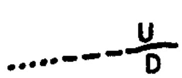
The Sacramento tuff and sand member is the youngest member of the Tuscan Formation in the area. The member has three distinct phases: predominantly tuff, 63 percent of section; tuffaceous volcanic sand, 25 percent; and volcanic conglomerate, 12 percent. The tuff phase is volcanic ash and sand. Pebbles and basic volcanic rocks are scattered throughout the tuff. The tuffaceous volcanic sand phase consists of sand formed from basic volcanic rocks,

# LEGEND

| Age | Symbol | Description |
|---|---|---|
| Recent | Qrsc | Stream Channel Deposits – gravel, sand, and silt in active stream channels. |
| | Qrfl | Flood Plain Deposits – sand, silt, and clay adjacent to active stream channels. |
| | Qral | Undifferentiated Alluvium – unconsolidated gravel, sand, silt, and clay. |
| | Qoal | Undifferentiated Older Alluvium – moderately consolidated cobbles, gravel, sand, and silt. |
| Pleistocene | Qrb | Red Bluff Formation – coarse gravel with a matrix of clay, minor sand and silt. |
| | Qfg | Fanglomerate – gravel and cobbles in a reddish brown clay matrix. |
| Plio–Pleistocene | QTte | Tehama Formation – fluvial deposits of sandstone, siltstone, and tuff with pebble and conglomerate lenses. Does not crop out in study area. |
| Pliocene | Ptu | Tuscan Formation (undivided) – interbedded volcanic rocks and volcanically derived sediments. |


Syncline

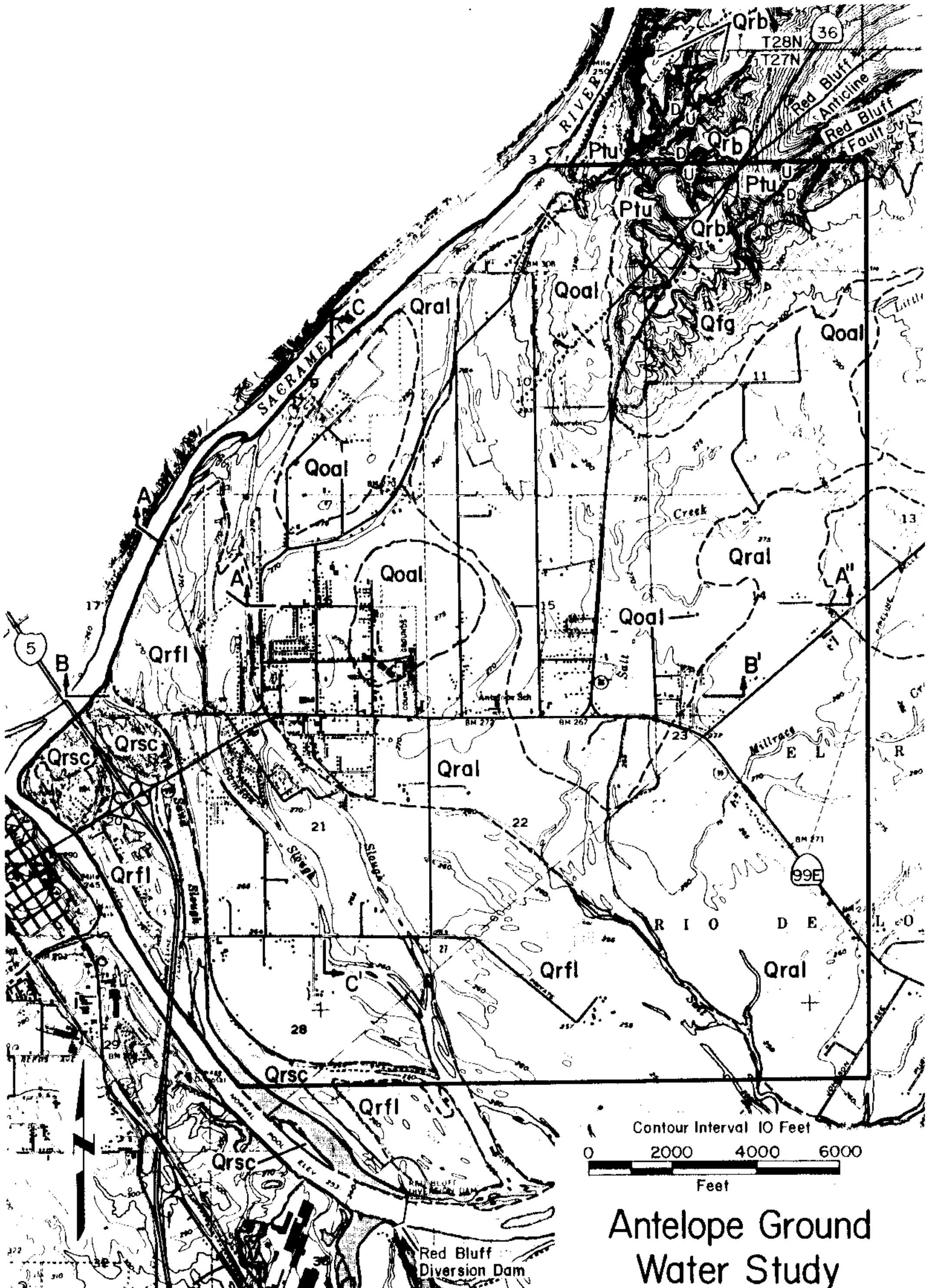

Anticline



Fault, dashed where approximately located, dotted where concealed. Relative movement as shown.

Line of geologic cross section

Figure 5




Antelope Ground Water Study Geologic Map

## Table 1

Description of Geologic Units
Antelope Study Area
Northern Sacramento Valley

| Geologic Age | | | Geologic Unit Map Symbol | General Character Location and Thickness | Water Bearing Properties |
|---|---|---|---|---|---|
| Cenozoic | Quaternary | Recent | Stream Channel Deposits Qrsc | Unconsolidated silt, sand and gravel occuring in and adjacent to active stream channel of the Sacramento River. May support soil and/or vegetation. Thickness can be up to 15 feet beneath the river. | Highly permeable; usually in contact with surface water; hydraulic continuity with older alluvial deposits. |
| Cenozoic | Quaternary | Recent | Flood Plain Deposits Qrfl | Unconsolidated sand, silt and clay deposited adjacent to active stream channel during (historic) periods of flooding. Thickness is less than 15 feet. | Wide range of permeabilities; generally above the water table. |
| Cenozoic | Quaternary | Recent | Undifferentiated Alluvium Qral | Unconsolidated deposits of clay, silt, sand and gravel. Thickness is less than 20 feet. | Moderately permeable; generally above the water table. |
| Cenozoic | Quaternary | Recent | Undifferentiated Older Alluvium Qoal | Moderately consolidated cobbles, gravel, sand and silt. Typically buried stream channel deposits. Thickness is less than 65 feet. | Highly to moderately permeable; hydraulic continuity with present day stream system; contains water table and upper zone of saturation. |
| Cenozoic | Quaternary | Pleistocene | Red Bluff Formation Qrb | Coarse gravel with a red silty clay matrix and minor interstratified sand and silt and local hardpans. Rests on the eroded surface of the Tehama Formation in the northern part of the study area. Thickness is less than 15 feet. | Poorly permeable; generally above zone of saturation; may contain shallow perched water. |
| Cenozoic | Quaternary | Pleistocene | Fanglomerate Qfg | Consists of layers of volcanic derived sand, gravel and silt, much of which is cemented. Directly overlies Tuscan Formation in the northeastern corner of the study area. Thickness is probably less than 50 feet. | Low permeability; unimportant as source of ground water in study area. |
| Cenozoic | Quaternary / Tertiary | Pleistocene / Pliocene | Tehama Formation Pte | Predominatly clay and silty clay with interbedded lenses of sand and gravel. The Tehama Formation interfingers with the Tuscan Formation at depth in the approximate vicinity of the Sacramento River and is overlain by Quaternary alluvial deposits. Maximum thickness is 2,000 feet. | Clayey materials are poorly permeable; gravel permeabilities range from low to high; often in hydrologic continuity with Recent and Quaternary alluvial deposits; both a free and confined ground water are present in Tehama aquifers; deep wells have moderate yields. |
| Cenozoic | Tertiary | Pliocene | contemporaneous deposition<br>Tuscan Formation Ptu | Interbedded tuff breccia, volcanic conglomerate, volcanic sandstone, siltstone and lappilli tuff. Principal area of exposure is east of the valley floor in the Cascade Range foothills. From there, the tuff breccias grade westerly into volcanic sands, gravels and clay. Volcanic sediments extend west of the Sacramento River where they interfinger with Tehama Formation. Thickness is less than 1,000 feet beneath the valley. | Volcanic sediments are moderately to highly permeable; tuff breccias, agglomerates and clays are confining units; poor hydrologic continuitity with alluvium; prinicipal source of ground water in the Antelope area; high yields can be obtained from Tuscan aquifers. |
| Cenozoic | Tertiary | | No Known Deposits | | |
| Mesozoic | Jurassic & | Cretaceous | Mesozoic Marine Sediment JK | Sandstone, siltstone, shale and limestone of marine origin. Exposed in small isolated areas east of the study area. Forms the Sacramento Valley basin boundary on the west side of the valley. Is overlain by Tehama-Tuscan sediments beneath the valley. | Mainly non water bearing or contains saline water. |

after USGS 1982, DWR 1978

with varying amounts of clayey and silty tuff. The conglomerate phase typically contains andesite and basalt pebbles with a sandy to silty tuffaceous matrix. This member is about 200 feet thick in Iron Canyon.

## Tehama Formation

The Plio-Pleistocene Tehama Formation does not crop out in the study area but is well exposed in the west Sacramento River banks and around Red Bluff. The Tehama Formation consists of fluvial deposits of predominantly thick-bedded, poorly sorted, pale-green, gray or tan-yellow sandy silt and clay. Gravel and sand interbeds are usually thin and lenticular. Mineral composition of the sediments indicates they were derived by erosion of the Coast Ranges to the west and Klamath Mountains to the north. The Tehama Formation interfingers with the Tuscan Formation in the approximate vicinity of the Sacramento River.

## Fanglomerate

The Pleistocene fanglomerate crops out east of State Route 36 on the hillsides north of Little Salt Creek. It is roughly contemporaneous with the Red Bluff Formation. The fanglomerate that flanks the Chico Monocline between Chico and Red Bluff is composed of alluvial fans that have merged to form a continuous plain of cobbles, gravel, sand, silt, and clay. Almost all material in the fanglomerate is composed of basic volcanic rocks derived locally from stream erosion and weathering of the Tuscan Formation. Typically, the fanglomerate consists of a clay matrix with gravel- to boulder-sized clasts. The iron-rich clay is oxidized and gives the formation a reddish-brown color. Exposed sections along streams that cut this plain stand with nearly vertical banks. Because the formation is so well cemented, much of the material should properly be called sandstone or conglomerate.

## Red Bluff Formation

The Pleistocene Red Bluff Formation crops out locally in the northern end of the study area. It is composed of very coarse gravel, with minor amounts of interbedded sand and silt. The clasts are generally nonvolcanic and nearly all derived from the Coast Ranges and Klamath Mountain Provinces. The characteristic red color is due to oxidation of the iron-rich matrix. Maximum thickness in the study area is about 15 feet.

## Older Alluvium

Undifferentiated Older Alluvium underlies most of the area immediately above the Tehama and Tuscan Formations. The Older Alluvium crops out east of Paynes Creek Slough and generally northeast of Antelope Boulevard. Floodplain deposits overlie the Older Alluvium from the Sacramento River east to Paynes Creek Slough and in the Salt Creek drainage south of State Route 99.

The Older Alluvium consists of poorly indurated, very coarse-grained gravel and cobbles, with medium- to coarse-grained sand and occasional silt. These deposits are up to 80 feet thick between the Sacramento River and Paynes Creek Slough. Between Paynes Creek Slough and Trinity Avenue, the deposit averages about 40 feet.

## Recent Alluvium

Undifferentiated Recent Alluvium occurs along Salt and Millrace Creeks and overlies the Older Alluvium along State Route 99E east of Paynes Creek. The Recent Alluvium consists of unconsolidated stream deposits of clay, silt, sand, and gravel. These deposits rarely exceed 15 feet in thickness in the study area, except east of Salt Creek, where they may be 25 feet thick.

## Floodplain Deposits

The floodplain deposits are mainly between Sand Slough and Paynes Creek Slough and south of State Route 99E, where they form an unbroken cover about 15 feet thick upon the Older Alluvium. They have been removed, or occur only locally, along the axis of the sloughs and are only intermittently present between Paynes Creek Slough and Sand Slough, where they range in thickness from 5 to 22 feet.

These materials are generally fine-grained, but they vary depending on age of deposition and proximity to the river. The deeply weathered, more clayey, moderately indurated deposits occur only east of Samson Slough. West of Samson Slough, the silts are increasingly loose and sandy.

## Stream Channel Deposits

Recent stream channel deposits occur under the Sacramento River and in Paynes Creek, Sampson Slough, and Sand Slough. These deposits are predominately coarse-grained cobbles and gravel, with sand and some fines. They are generally loose and unconsolidated and are deposited on the Tuscan Formation, the Tehama Formation, or the Older Alluvium.

# CHAPTER 5. HYDROGEOLOGY

This section is organized to: (1) give the reader background material to understand the occurrence and movement of ground water, (2) describe the water-bearing formations in the Antelope area, and (3) discuss ground water movement in the Antelope area.

## Principles of Ground Water Hydrology

The movement of a drop of water from the time it enters the ground to the time it comes out, either naturally or by being pumped from a well, is controlled by underground conditions. Upon entering the ground, the water moves downward through the zone of aeration and into the zone of saturation, the upper surface of which is the water table.

This happens whenever water from precipitation, streamflow, irrigation, and other sources sinks into the ground, and the area into which it sinks is called a "recharge area". Recharge areas are on mountains, foothill slopes, and valley floors. Alluvial deposits on valley floors that are hydrologically connected to rivers and streams are often important recharge areas.
The deposits are usually very permeable, allowing for rapid infiltration.

### Ground Water Contour Maps

General ground water movement in a valley can be interpreted from maps that show lines of equal elevation of the water table. From such a map, the direction of ground water movement is interpreted as being at right angles to the contour lines and moving from the higher elevation contour to the lower, or from areas of recharge to areas of discharge. Under typical water table conditions, the slope of the water table and, therefore, the direction of ground water movement are closely related to the slope of the land surface. Under natural conditions, the rate of ground water movement in an aquifer is usually slow, from a few feet to a few hundred feet per year. However, pumping can create a temporary depression in the water table and change the direction and rate at which ground water moves--toward the well instead of down the natural gradient.

Often, physical barriers that impede the movement of ground water are indicated by the patterns or spacings of the ground water contours. The effect of geologic faults on the movement of ground water can often be interpreted from contour maps. Where a fault offsets a water-bearing layer, ground water may be dammed, forming a higher water table on the recharge side, or may rise along the fault zone, and appear at the ground surface as springs. If the ground water has percolated deep enough to become heated and mineralized, it will appear at the surface as a hot spring such as Tuscan Springs.

## Ground Water Occurrence

Most of the materials that make up the earth's outer crust have open spaces that may contain ground water. These openings range from minute pores in clays and small cracks in rocks to large lava tubes found in some basalt flows. Porosity, or the percentage of empty space in a material, does not necessarily mean ground water can move through the material easily. If the openings are very small or are not connected, the material is said to have a low permeability, even though its porosity may be high. Thus materials of low permeability and high porosity, such as clay and tuff, transmit little water to wells. In contrast, materials of high permeability but somewhat lower porosity can yield large amounts of ground water. Materials of this type include fractured basalt and mixtures of coarse gravel and sand.

Underground water is present in two major zones beneath the ground surface. Figure 6 shows the occurrence of ground water within these zones. In the upper zone, or zone of aeration, most of the openings in the geologic materials are filled partly with air and partly with water, and conditions may approach saturation due to infiltration of rainfall or irrigation water. Wells cannot produce ground water from the zone of aeration. "Perched" ground water can occur in an isolated saturated zone separated from the main body of ground water by some layer of rock or clay that water cannot pass through. Well "B" in Figure 7 represents a well yielding water from a perched water table.

In the lower zone, or zone of saturation, openings in the underground materials are interconnected and filled with ground water. Ground water exists in this zone under unconfined or confined conditions, or some condition between the two.

An unconfined aquifer has no impervious layer over it. It can be recharged from direct precipitation and surface runoff. The water table is the upper surface of the water in the saturated zone, approximately the level to which water will rise in a well. Well "D" in Figure 7 represents a well tapping an unconfined aquifer.

Confined ground water has an impervious layer over it. It moves through the ground under pressure. It cannot receive direct recharge; rather, recharge occurs upslope of the confining (impervious) layer. The level to which confined ground water will naturally rise in a well (because it is under pressure) is called the "piezometric surface". When this surface is below ground, the water level will rise to some point, as represented by Well "A" in Figure 7. If the piezometric surface is above ground, the well will flow, as represented by Well "C", and is called "artesian".

Most of the water level data in this report are composite. That is, they do not represent conditions in any specific aquifer. Instead, due to construction characteristics of monitoring wells, each water level measurement represents only an average for all water-bearing strata penetrated by a particular well. More detailed data can be obtained only from qualified wells (wells with logs and information on the placement of perforations in the casing) which are perforated in a single stratum.

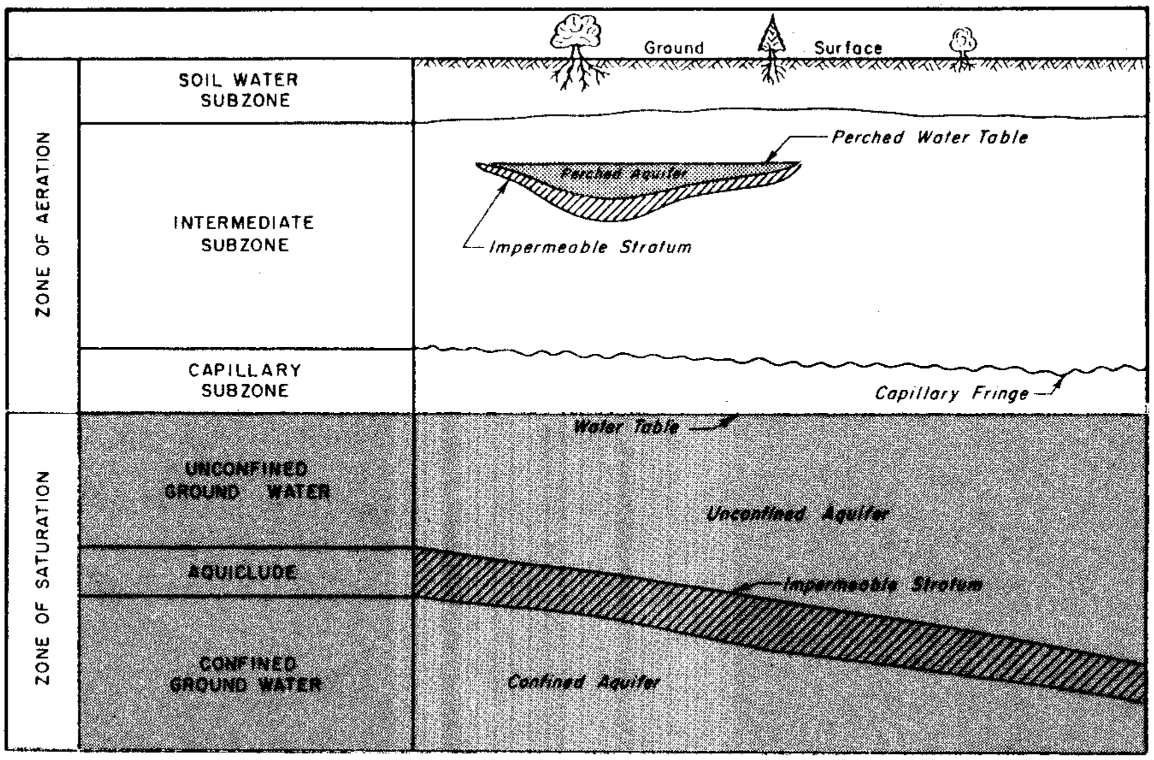



Figure 6 Occurrences of Ground Water.

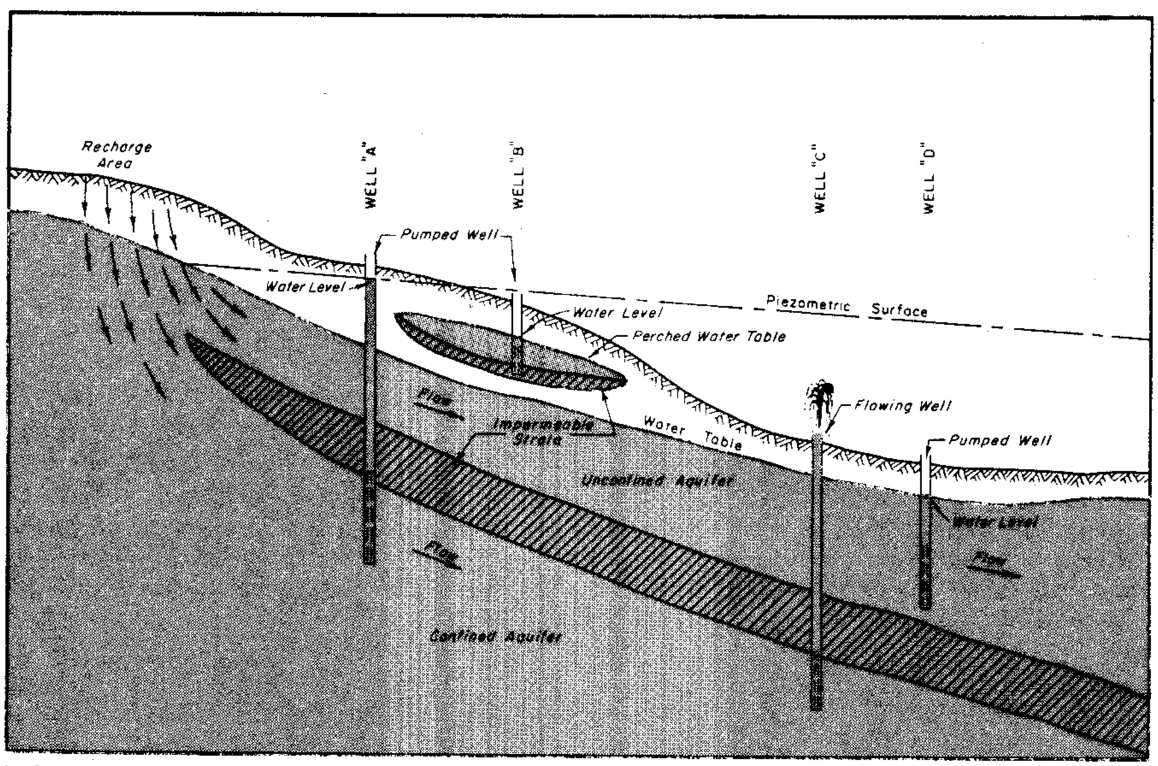



Figure 7 Unconfined and Confined Ground Water.

## Changes in Water Levels

Determination of the occurrence, movement, and fluctuations of ground water is made by analyzing water level data from key wells throughout a ground water basin. These data can show both seasonal and long-term changes in water levels. Historical records of water levels are helpful in detecting trends in ground water storage in a basin. A comparison of streamflow, precipitation, and water level data can indicate early signs of potential overdraft.

When a well is pumped, the water level around it is drawn down to form an inverted cone with its apex at the well. This cone of depression in the static water surface is shown in Figure 8. The size of this cone of depression depends on how much water is being pumped and how fast water can flow through the aquifer to replenish the well. As pumping continues, the cone expands in depth and area until it reaches equilibrium between pumping demands and aquifer yield.

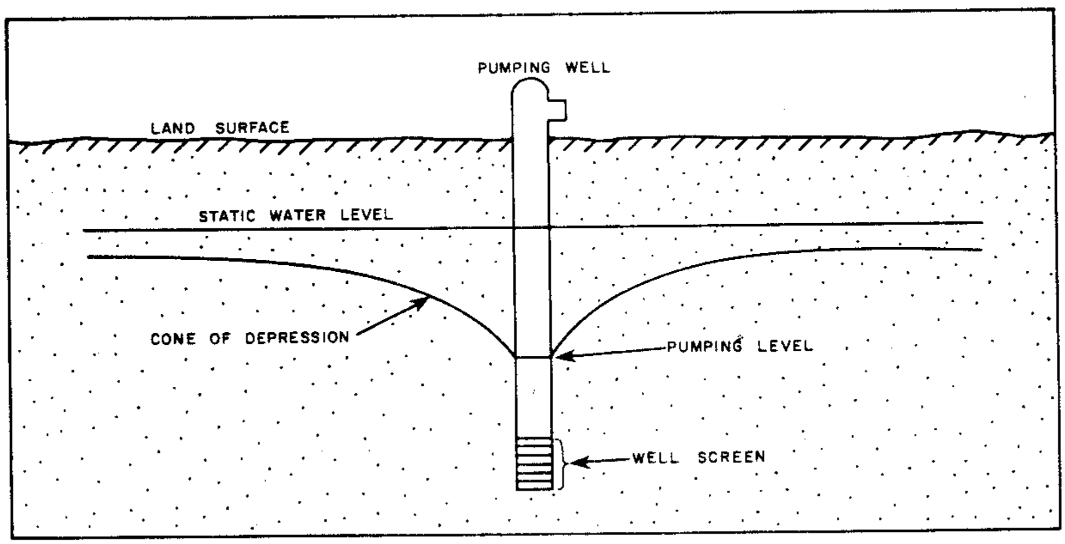



**Figure 8 Cone of depression caused by pumping wells.**

Where recharge is less than the amount of water pumped from an aquifer, water levels will continue to decline. Where intensive development has taken place in ground water reservoirs, the cone of depression of each well overlaps with those of neighboring wells, producing a regional cone of depression and lowering water levels. Figure 9 illustrates the effects of this interference among pumping wells. The extent of interference depends on the rate of pumping from each well, the spacing between wells, and the hydraulic characteristics of the aquifer into which the wells are drilled.

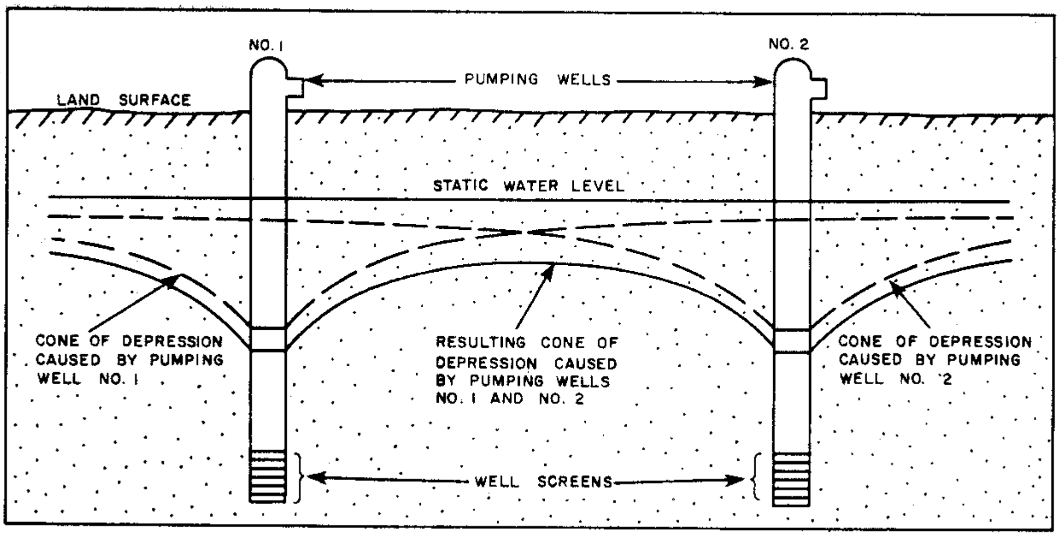



**Figure 9 Effects of interference between two pumping wells.**

## Water-Bearing Formations

The main aquifers in the study area are in the Tuscan and Tehama Formations, which contain fresh water to a depth of 1,500 feet and brackish water (>3,000 micromhos) below 1,500 feet (USGS, 1961). The Recent Alluvium and Older Alluvium yield limited amounts of ground water and, thus, are not considered to be aquifers in the Antelope area.

Eighty well drillers reports for irrigation, industrial, municipal, and domestic wells were reviewed. Table 2 summarizes the yield, well depth, and specific capacity data from these reports. Many of the pump tests were conducted after completion of the wells and over a short period before steady-state conditions were reached. Therefore, the data must be evaluated with caution.

Table 2. Summary of Antelope Well Log Data

| Formation Containing Aquifer | Yield (gpm) | | Well Depth (ft) | | Specific Capacity (gpm/ft) | |
|---|---|---|---|---|---|---|
| | Average | Range | Average | Range | Average | Range |
| Tuscan | 332 | 15-2500 | 160 | 68-628 | 30 | 2-208 |
| Tehama | 69 | 15-200 | 101 | 52-200 | 18 | 2-60 |

The deepest well is 628 feet. Tuscan Formation aquifers were penetrated by 56 wells, or 70 percent of the total. Five percent were perforated in both the Tehama and Tuscan Formation aquifers. The other 25 percent penetrated the Tehama aquifers.

The floodplain deposits, Recent stream channel deposits, fanglomerate, and Red Bluff Formation are of limited extent, and no known wells produce from them in the Antelope area. No Antelope area wells produce from the underlying Great Valley Sequence rocks, which are about 3,500 feet below the ground surface. Therefore, these units are not discussed.

Data from Iron Canyon Investigation exploration drill holes (USCE, 1947), Red Bluff Diversion Dam investigation, and Caltrans bridge borings permitted delineation of formational contacts (Figures 10, 11, and 12), and some hydrogeologic marker beds. The water well drillers reports do not contain detailed lithologic descriptions similar to the damsite and bridge borings. Therefore, they could be used only to establish general formational contacts; individual lithologic units within the formations generally could not be delineated.

To evaluate the hydrogeologic characteristics of the Recent and Older Alluvium and the Tehama and Tuscan Formations, water well drillers reports were used to classify the materials. Although many logs reported only gravel, sand, and clay or gradations between these primary units, other logs reported as many as 10 to 20 types of material, including color, texture, and origin descriptions. After a review of the many types of materials described, the materials were grouped into two categories:

- Coarse-grained: gravel, rock, sand, mixed gravel and sand, and mixed gravel and clay.

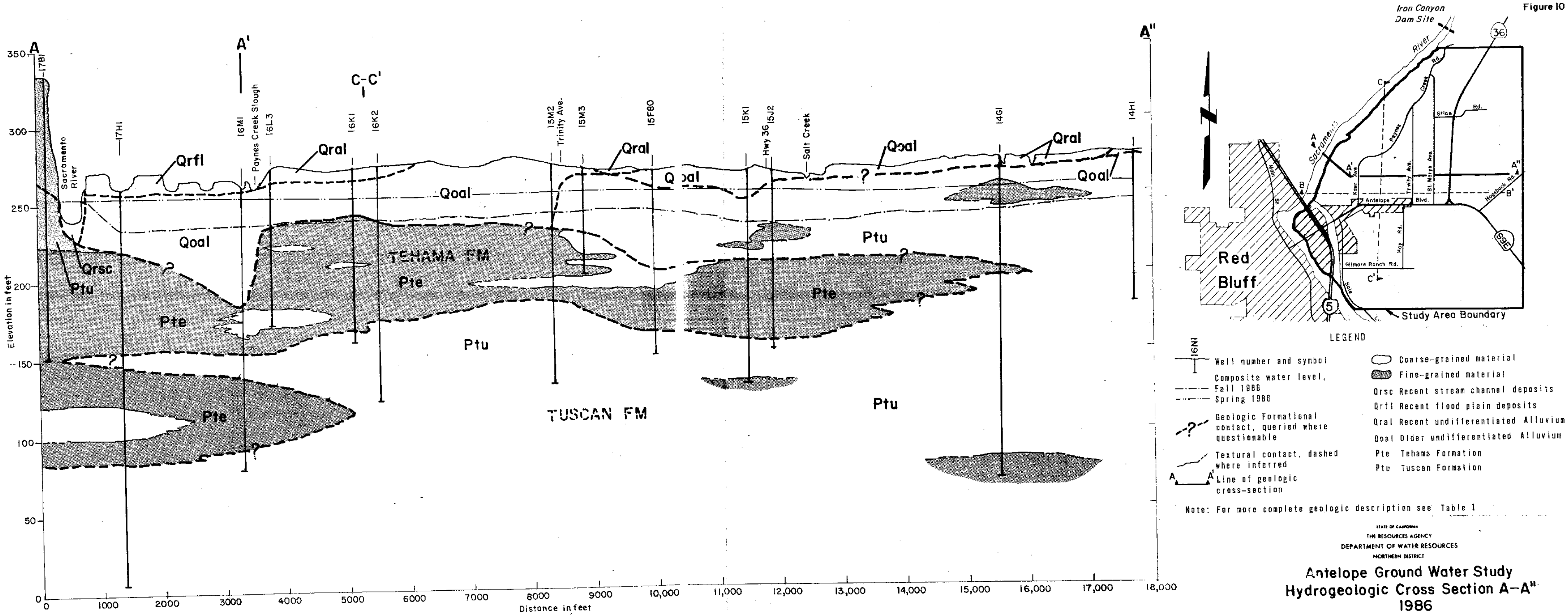
- Fine-grained: clay, shale, sandstone, and mixed clay and gravel.

Sand, sand and gravel, and clay and gravel were grouped into both categories because all gradations occur, from clayey to sandy gravel to gravel. Clay, silt, sandy clay, hardpan, and other clayey materials were grouped into the fine-grained category because of their impermeable character. Cross sections AA'A", BB', and CC' depict the two general groups (Figures 10, 11, and 12).

## Tuscan Formation

The Tuscan Formation is the major source of ground water in the Antelope area. Beneath Antelope, the Tuscan Formation is as much as 2,000 feet thick. The formation is essentially volcanic, derived mainly from pyroclastic debris. It consists of mudflows, volcanic breccias, tuff breccias, lapilli tuff, and tuff. Between mudflows are permeable stream deposits of sand and gravel. Beginning at about the eastern edge of the valley, extensive alluvial fans were developed from erosion and redeposition of the mudflows. The net result is a change in character from predominantly mudflow deposits in the Cascades east of the valley to volcanic gravel, sands, clays, and tuffs beneath the valley.

Figure 10

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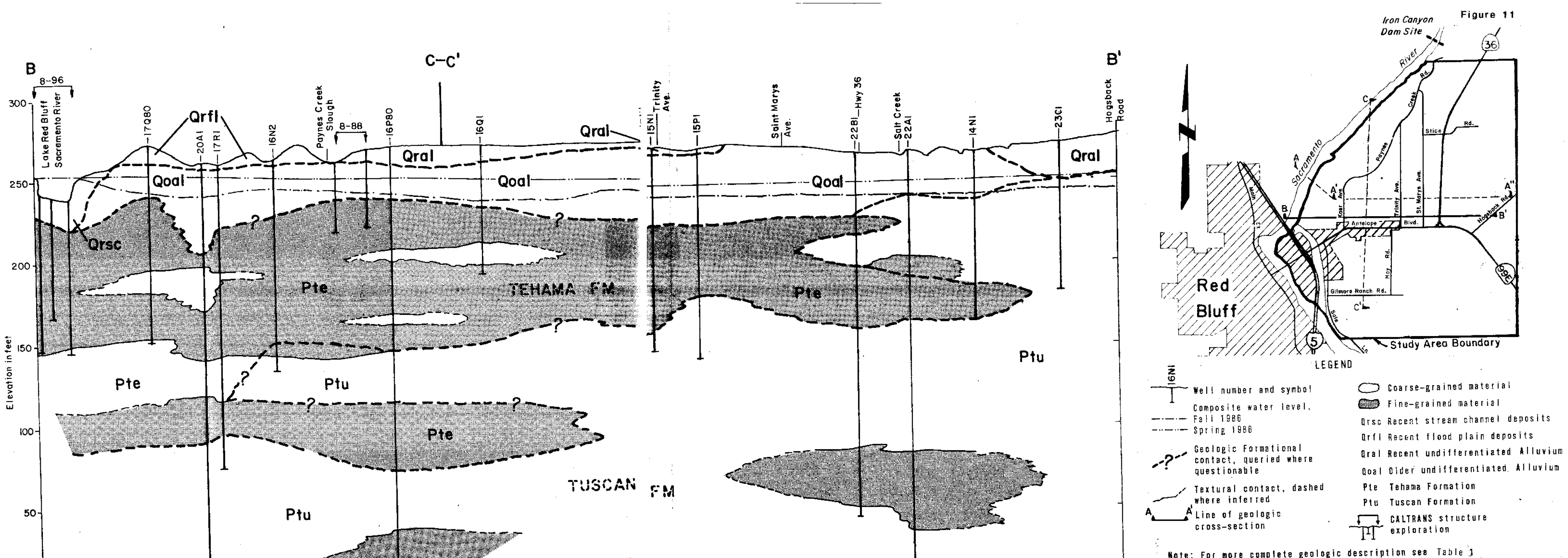
**Antelope Ground Water Study**
**Hydrogeologic Cross Section A–A"**
**1986**

Figure 11

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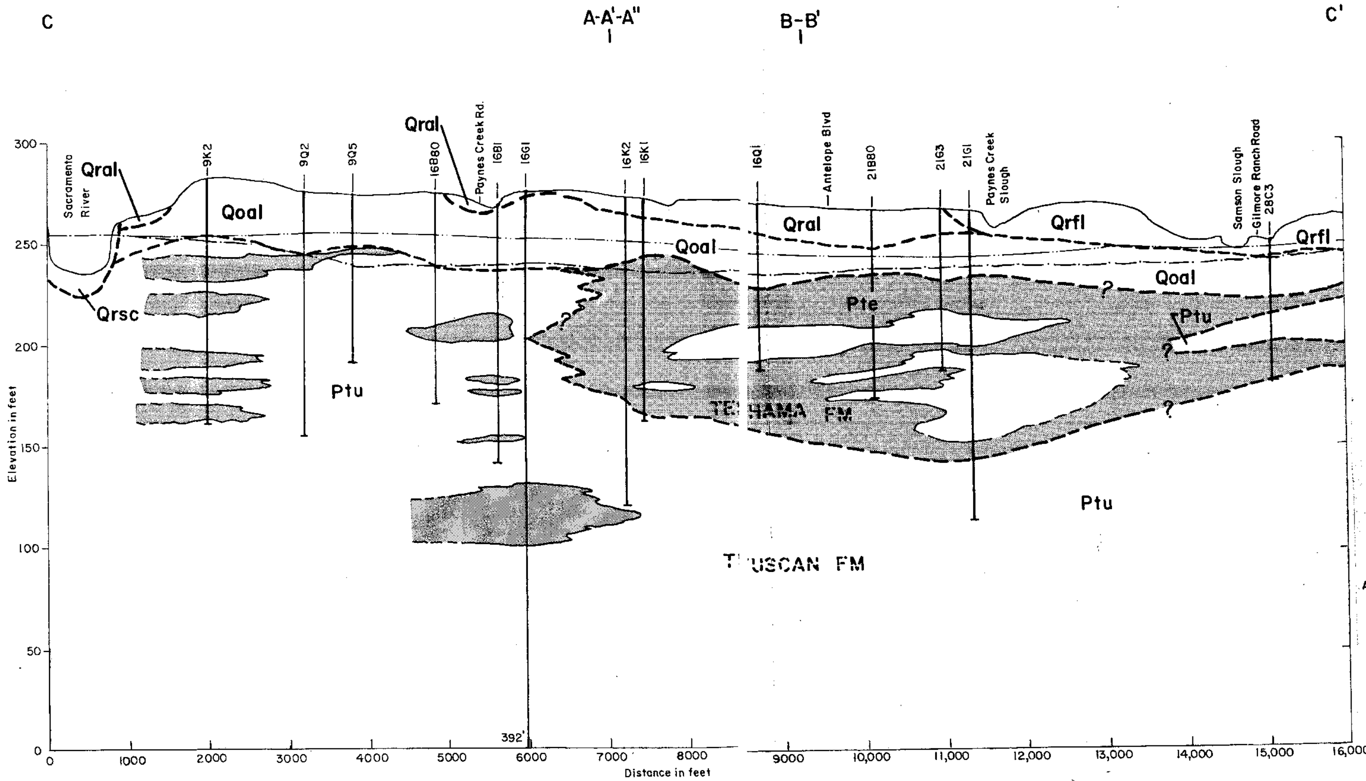
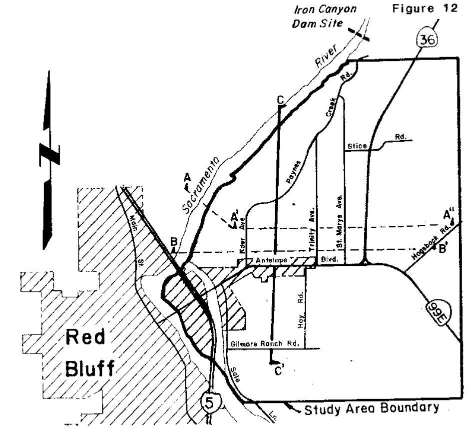
**Antelope Ground Water Study**
**Hydrogeologic Cross Section B–B'**
**1986**

Figure 12




LEGEND

| | |
|---|---|
| 16N1 Well number and symbol | Coarse-grained material |
| Composite water level, Fall 1986, Spring 1986 | Fine-grained material |
| Geologic Formational contact, queried where questionable | Qrsc Recent stream channel deposits |
| Textural contact, dashed where inferred | Qrfl Recent flood plain deposits |
| A A' Line of geologic cross-section | Qral Recent undifferentiated Alluvium |
| | Qoal Older undifferentiated Alluvium |
| | Pte Tehama Formation |
| | Ptu Tuscan Formation |

Note: For more complete geologic description see Table 1

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**Antelope Ground Water Study**
**Hydrogeologic Cross Section C–C'**
**1986**

The sand and gravel aquifers of the Tuscan Formation are confined to semiconfined by the tuffs, tuff breccias, and clay aquicludes and aquitards. The aquifers act as conduits for ground water movement into the valley from the recharge areas in the Cascade Range foothills to the east (DWR, 1978). Recharge of the aquifers is primarily by the westerly draining streams east of the valley (USBR, 1953).

Few of the individual Tuscan Formation aquifers were delineated. In places beneath the valley floor, thick layers of sand and sand-and-gravel aquifers indicate that the uppermost zone could be considered as one confined aquifer system. However, water level and geologic data suggest that in other places the Tuscan aquifers are semiconfined.

The Tuscan Formation is considered to be moderately permeable (DWR, 1978). Locally, the volcanic sands yield large amounts of water to wells. Specific capacities of wells that penetrate Tuscan aquifers in the Antelope area range from 2.0 to 208 gpm/ft, and average 30 gpm/ft (see Table 2).

## Tehama Formation

The Tehama Formation is derived from deposits of the ancestral Sacramento River and easterly draining streams (USBR, 1953). The Tehama Formation is composed principally of silt and clay, with sand and gravel lenses. Because of thickness and widespread distribution, the Tehama Formation is an important source of ground water, particularly west of the Sacramento River. Good sand and gravel aquifers occur in the Tehama Formation, and many have been identified on Figures 10, 11, and 12. The deposits interfinger with and overlie Tuscan Formation deposits from the east.

The Red Bluff Diversion Dam report (USBR, 1953) found that both free and confined ground water are present in Tehama aquifers at the dam. Review of well drillers reports and water level measurements indicate that most Tehama aquifers more than 100 feet deep are confined, and those less than 100 feet deep are semiconfined or free.

The Tehama Formation is less permeable than the overlying alluvial deposits. Specific capacities from Tehama aquifers range from 2 to 60 gpm/ft and average about 18 gpm/ft (see Table 2).

Recharge of relatively shallow aquifers is from vertical percolation of precipitation and applied water in the valley floor and/or from seepage along the Sacramento River and streams where the Tehama Formation crops out (DWR, 1970). Recharge of the deeper, less permeable Tehama aquifers is from the west and northwest (USBR, 1953).

## Recent and Older Alluvium

Recent Alluvium and Older Alluvium overlie the other formations and occur in the floodplains and stream channels. Thickness of the deposits varies and is generally 15 to 30 feet, except for the Older Alluvium between the Sacramento River and Paynes Creek Slough, where it is about 60 feet thick. The Recent alluvial deposits are quite permeable, with occasional thin discontinuous silt and clay beds.

## Ground Water Level Fluctuations and Movement

Ground water levels in the Antelope area normally fluctuate on an annual basis. They are highest in the spring and lowest in the fall. From spring through fall, levels are lowered by discharge to streams, domestic and irrigation pumpage, and evapotranspiration by plants. Levels begin to increase in the winter, when recharge exceeds losses. Long-term fluctuations occur when net recharge is either greater than or less than net discharge.

Ground water levels were monitored from June 1985 through December 1986 in about 80 Antelope area wells. These wells were chosen for measurement because they were qualified from a well drillers report so that the water sources in each well could be determined.

The Antelope area wells are perforated in the Tuscan and Tehama Formation aquifers, but generally not in Recent or Older Alluvium. Water levels indicate that most of these wells are not confined, but appear to be composite. In fact, the composite levels are at about the same elevation as the free ground water levels in the Antelope area. This could occur if the Tuscan and Tehama confined aquifer systems are leaky or if the well casings and seals allow free ground water to enter the well casing.

Free ground water occurs in the Older and Recent Alluvium and in the upper 50 to 100 feet of the Tehama Formation. Only a few water wells penetrate just the free system in the area, so free ground water cannot be contoured.

Free ground water is recharged by precipitation in the drainage basin, infiltration of applied irrigation water, percolation of septic effluent, and seepage from Salt Creek and the Sacramento River. Sacramento River flow at Red Bluff is controlled nearly year-round by Shasta Reservoir, Keswick Afterbay Reservoir, and Red Bluff Diversion Dam. The diversion dam has been operating since 1966. During the irrigation season, from April 15 to November 15, the surface level of the reservoir is maintained at 252.5 feet; the rest of the year the control level is reduced to 251.5 feet.

The 1966 closure of the Red Bluff Diversion Dam caused ground water levels to rise. Well 28L1 penetrates 44 feet into the Older Alluvium about 1,200 feet east of the Sacramento River. Well 28L1 hydrograph (Figure 13) indicates Older Alluvium is hydrologically connected with the Sacramento River. Prior to the diversion dam construction, USBR semiannual records for 1962 to 1966 in well 28L1 showed an average ground water elevation of 240 feet. After the diversion dam was put into operation, the elevation increased to 248 feet, showing the influence of Lake Red Bluff. Semiannual ground water levels show little fluctuation between spring and fall, because the lake level is held nearly constant.

Well 10N1 penetrates 307 feet in Tuscan Formation about 2,000 feet from the Sacramento River, north of the area influenced by Lake Red Bluff. Well 10N1 hydrograph in Figure 13 indicates semiannual ground water level fluctuations. These levels are greatly influenced by annual precipitation. During the drought in 1977, ground water levels decreased due to limited precipitation. During 1978 and 1983, when annual precipitation exceeded 30 inches, ground water levels increased.

A spring 1962-1986 water level change map (Figure 14) was constructed using wells that measure free ground water levels and river water surface elevations. The map shows up to a 10-foot increase in ground water levels over much of the southern portion of the study area.

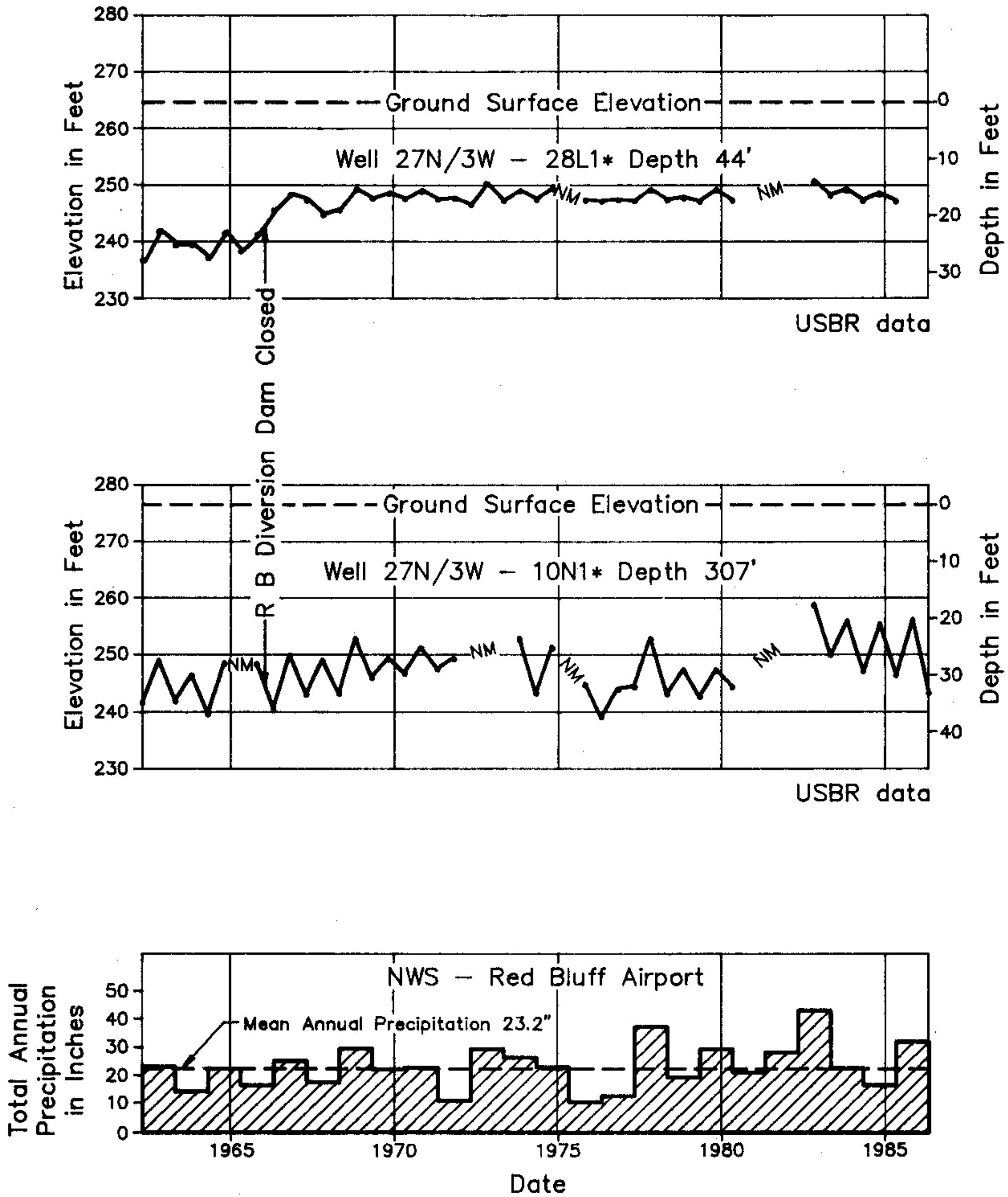
The spring 1986 water elevation map (Figure 15) shows that Antelope water elevations are very near the Lake Red Bluff water surface elevation of 253 feet. Direction of ground water flow, as shown by arrows, indicates that recharge is from both the Sacramento River and Little Salt Creek. The recharge sources are confirmed by the ground water quality analysis presented in Chapter 7.

The fall 1986 water elevation map (Figure 16) shows that water levels were locally drawn down 10 to 15 feet below the spring elevations. The ground water flow arrows show that recharge continues to come from both the river and Little Salt Creek.

The spring-fall 1986 change map (Figure 17) shows several 15-foot depressions north of Antelope Boulevard. These may be areas of higher ground water withdrawal. The depressions may also suggest that Lake Red Bluff recharge is not as effective at the north end of the reservoir as it is to the south, where the increased river stage is higher.

The depth to water map for spring 1986 (Figure 18) shows that near Lake Red Bluff the ground water is very shallow. North of Antelope Boulevard, along State Route 36E, the ground water surface is fairly level, but the ground elevation and depth to water increase rapidly. This again suggests that Lake Red Bluff and the Sacramento River are the prime sources of recharge for the shallow aquifers in the Antelope area.

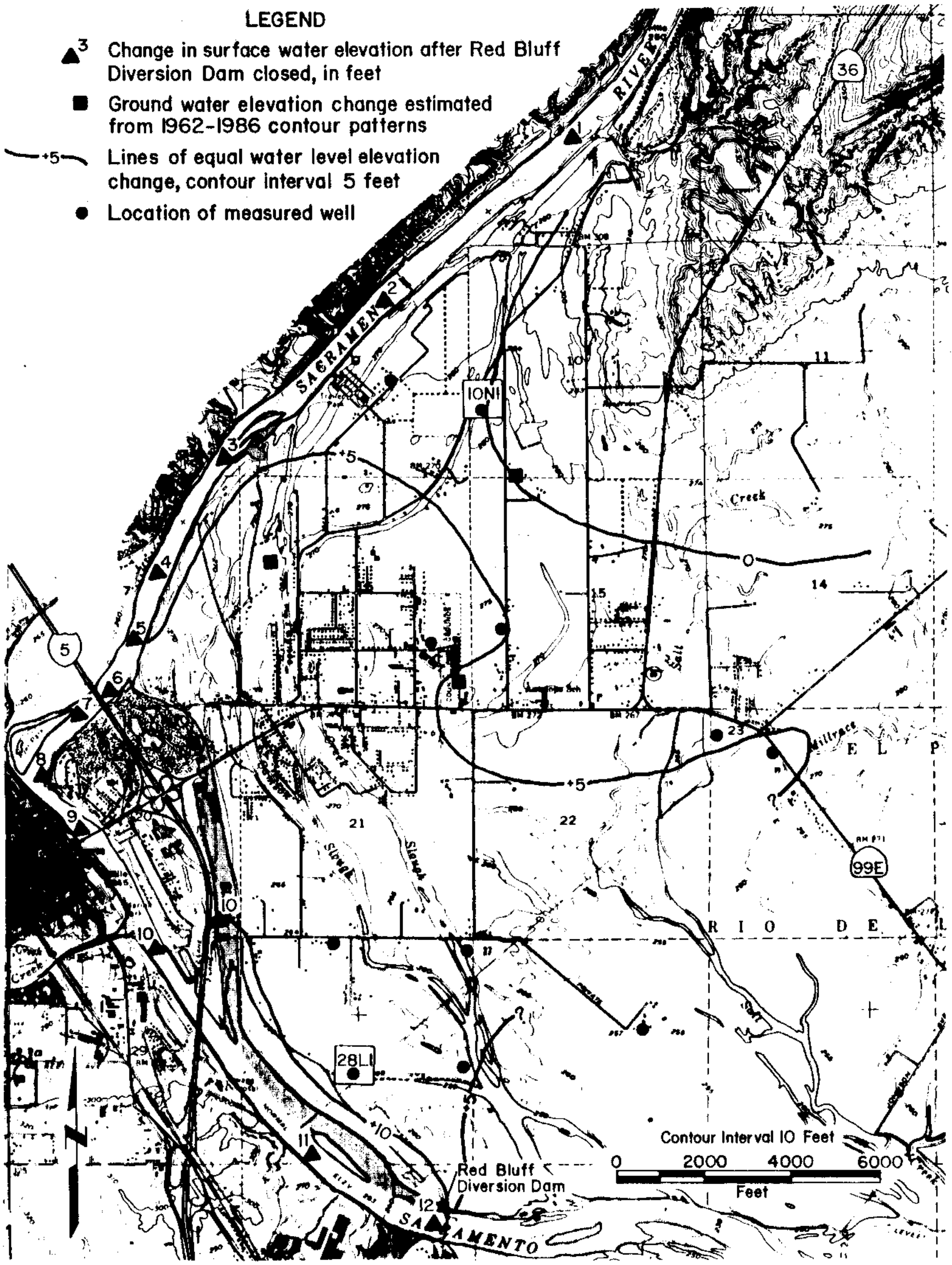
Figure 13




* For Well Location See Figure 14
NM= No Measurement

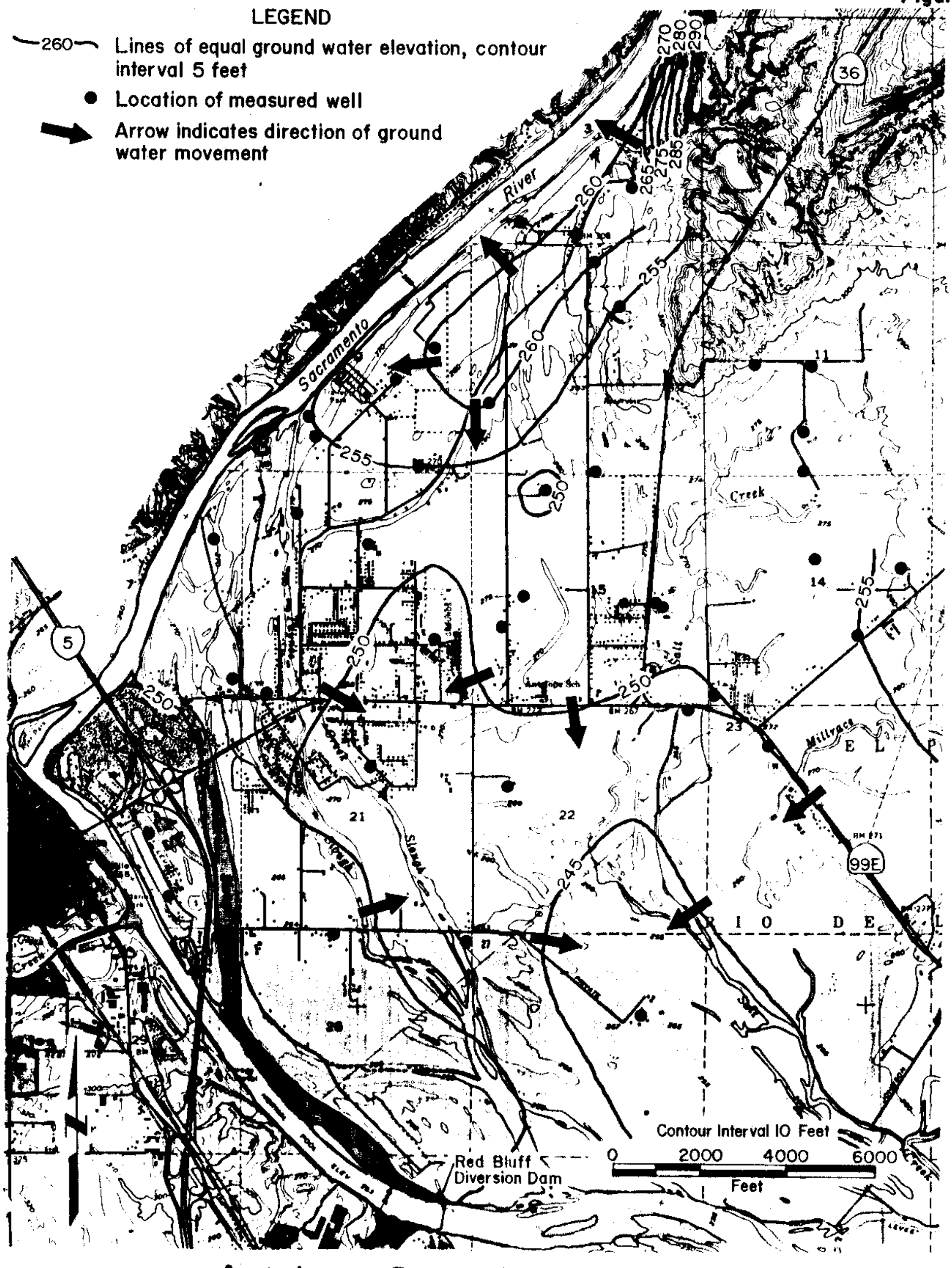
# Antelope Ground Water Study Hydrographs of Selected Wells and Precipitation Station

Figure 14



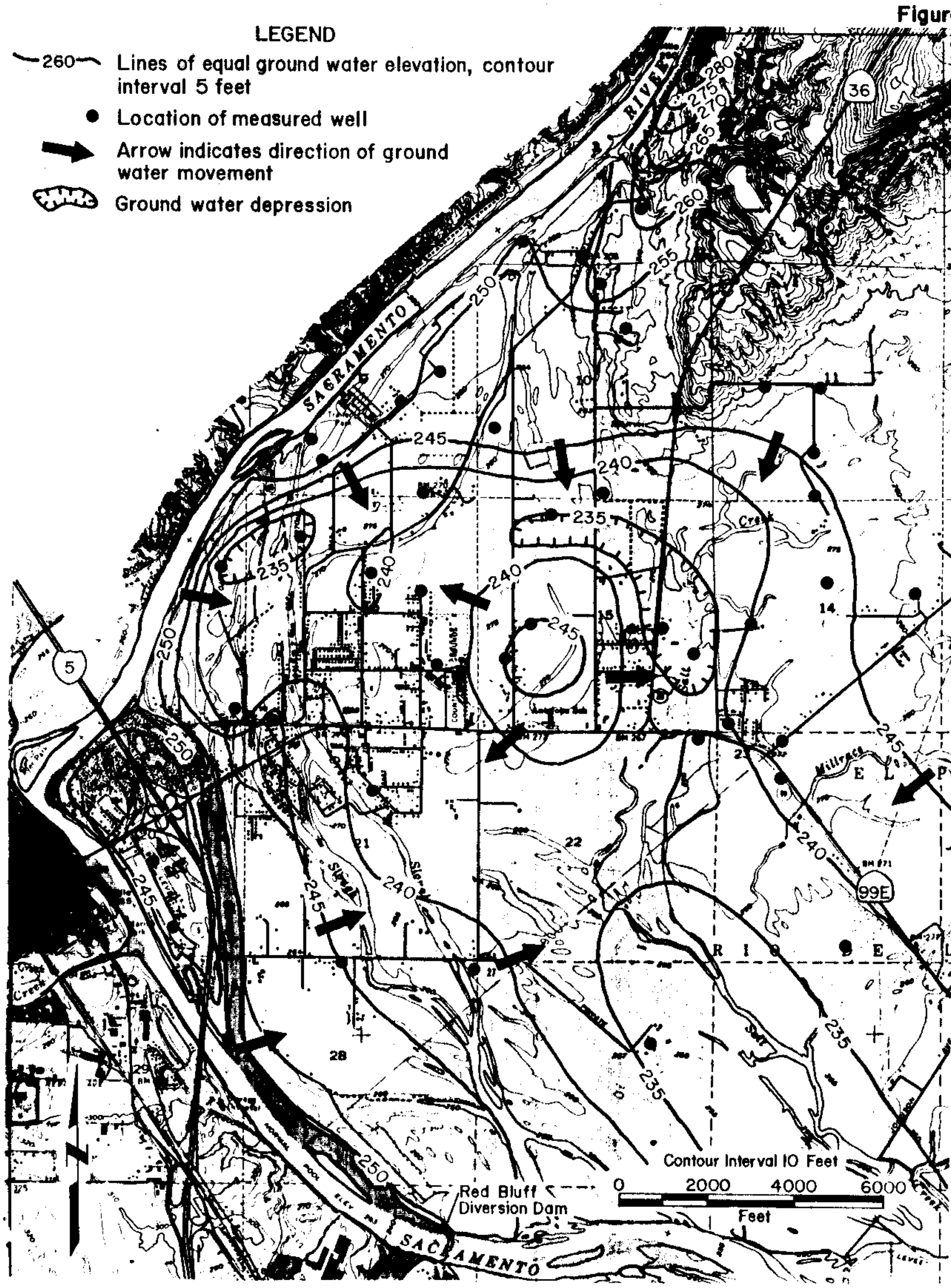

Antelope Ground Water Study
Change in Water Level Elevation Spring 1962 to 1986

Figure 15

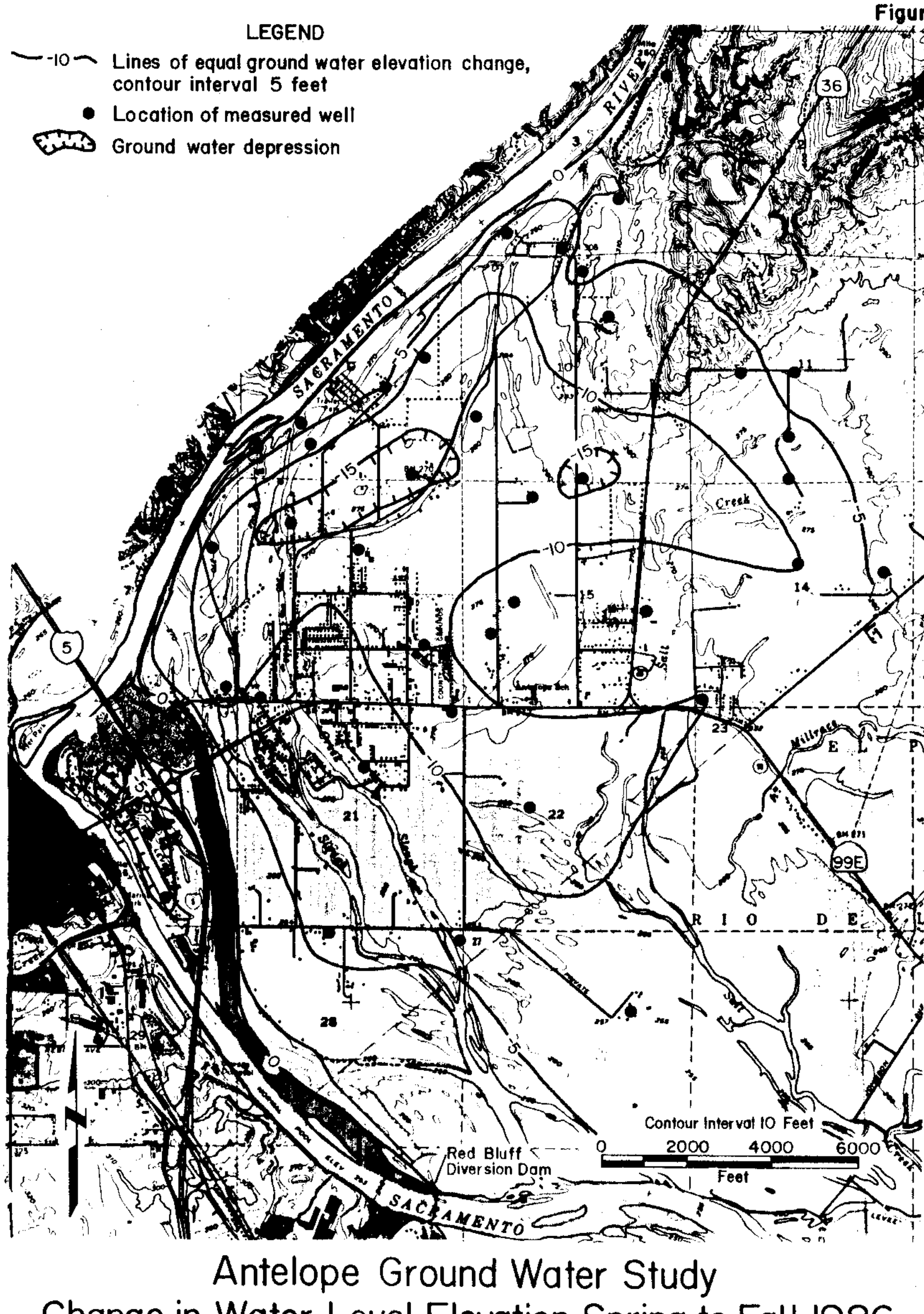



Antelope Ground Water Study
Water Level Elevation, Spring 1986

Figure 16

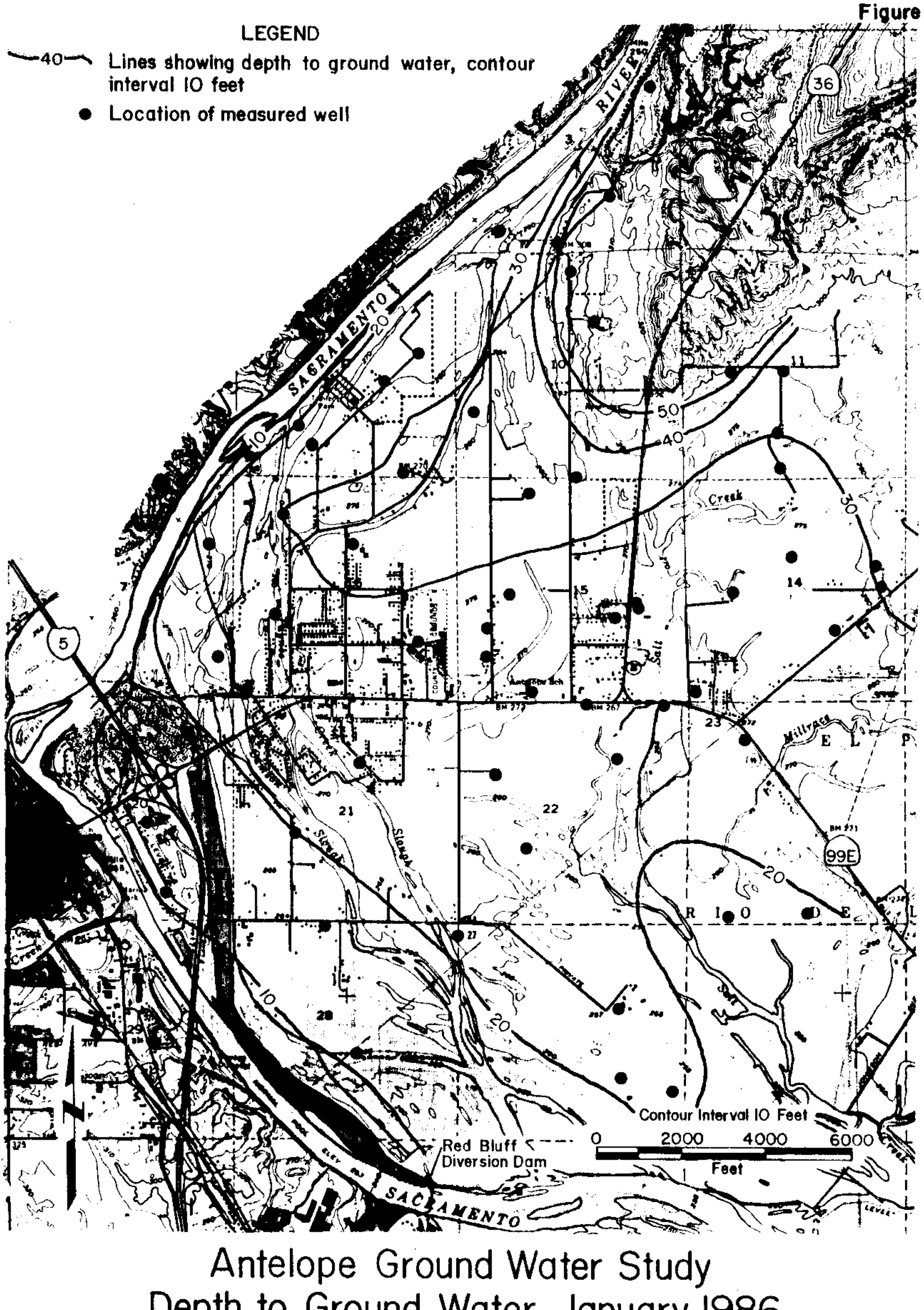



Antelope Ground Water Study
Water Level Elevation, Fall 1986




Antelope Ground Water Study
Change in Water Level Elevation, Spring to Fall 1986

Figure 18




Antelope Ground Water Study
Depth to Ground Water, January 1986

# CHAPTER 6. GROUND WATER QUALITY

This chapter presents information on water quality parameters, sampling and analytical procedures, and water quality criteria. The mineral quality of ground water in the study area is discussed, and problems with the water quality are examined.

## Water Quality Parameters

The suitability of ground water for domestic and agricultural uses is largely determined by the quality of the original recharge waters and by the material it passes through. Water derived from precipitation is an excellent solvent. It contains dissolved gases, such as carbon dioxide and oxygen, but normally contains few dissolved solids. As water passes through the hydrologic cycle, it dissolves minerals from the materials it contacts. The amount and type of minerals dissolved reflect the composition of these materials and the hydrologic and geologic conditions governing the rate of water movement. Often, salts and other pollutants are added by sewage, industrial wastes, and irrigation return flows. These dissolved substances can determine water's suitability for beneficial uses.

A measure of the overall chemical quality can be obtained by determining and summing the concentrations of individual ions in a water. A measure of the total dissolved solids (TDS) can also be obtained by measuring the electrical conductivity of the water sample, as that value can be related to the ionic content of the water. Ions commonly found in natural waters and most often looked for in laboratory analyses include calcium, magnesium, sodium, potassium, bicarbonate, carbonate, sulfate, chloride, and boron. Each of these is important to one or more beneficial uses.

Another important chemical factor is pH, a measure of acidity (hydrogen ion content). The pH scale ranges from 0 to 14, with a value of 7 being neutral. Most natural ground waters have a pH in the 6.5 to 8.5 range, while an acid such as lemon juice has a pH of about 2 and household ammonia has a pH of about 12.

Alkalinity is a measure of a water's ability to withstand changes in pH and is due to the carbon dioxide, bicarbonate, and carbonate equilibrium in the water. The buffering action of this equilibrium is important, because it dampens pH fluctuations that might occur due to waste discharges. It also serves as a source of inorganic carbon for plant growth.

Water contains varying amounts of certain elements essential to biologic productivity that are referred to as nutrients. Such metals as iron, copper, and molybdenum are needed in trace amounts and are called micronutrients. Carbon, nitrogen, and phosphorus are needed in larger quantities and are referred to as macronutrients. Nitrogen is found in water in the form of nitrate, nitrite, ammonium ion, and ammonia gas, and as part of nitrogen-bearing organic compounds. Nitrate is the form most commonly found in ground water.

## Sampling and Analytical Methods

To determine the present quality of Antelope ground water, sampling was conducted in the summers of 1985 and 1986. DWR's regular monitoring program wells were included so that present quality could be evaluated in relation to historical variation. Ground water samples were collected in sample-rinsed plastic bottles from taps at the wells or from the nearest possible point in the distribution system. Whenever possible, samples were collected when pumps had been operating for a period of time so that the quality would represent the well's source aquifer. Temperature, pH, and EC measurements were made at the time of sampling, and additional samples were collected for analyses at the DWR chemical laboratory in Bryte.

Temperatures were measured with standard field thermometers whose calibrations had been checked in the laboratory.

Field pH was determined by using Hellige Comparitors with appropriate indicator solution and disk. Laboratory pH was also measured in selected samples with a calibrated glass electrode-type pH meter.

EC was measured on portable Beckman solubridges that had been calibrated on known solutions. Selected samples that were sent to the laboratory also had EC determinations made for quality control.

Samples collected for standard mineral or special constituent determinations were transported to the Bryte Laboratory for analysis. Table 3 lists the standard methods used at that laboratory and at the Shasta County Health Department for bacteria.

Table 3. Analytical Methods for Water Quality Parameters

| Parameter | Method |
|---|---|
| Electrical Conductivity | Beckman Wheatstone Bridge |
| Total Hardness | Ca, Mg Atomic Absorption Spectrophotometric |
| Sodium | Atomic Absorption Spectrophotometric |
| Potassium | Atomic Absorption Spectrophotometric |
| Sulfate | Gravimetric - AWWA |
| Chloride | Automated Ferricynate Method |
| Boron | Carmine - AWWA |
| Dissolved Nitrate | Automated Cadmium Reduction |
| Total Ammonia | Automated Phenate |
| Total Organic Nitrogen | Block Digestor Phenate |
| Dissolved Phosphate | Automated Ascorbic Acid |
| Total Phosphate | Block Digestor Ascorbic Acid |
| Bacteria (Coliform Group) | Multiple-Tube Fermentation |

Water samples taken during this study for total and fecal coliform bacteria determination were collected by Tehama County personnel in clean, sterilized bottles at a tap nearest the well. All samples were delivered to the Shasta County Health Department Laboratory within six hours after collection. Ice chests were used for storage of water samples during transport to the laboratory.

## Water Quality Criteria

The two major uses of ground water in the Antelope area are domestic and agriculture, so water quality criteria for each were used in the evaluations. Except for constituents considered toxic to humans, concentrations included in the criteria are "suggested" limiting values. Water that contains constituent concentrations exceeding these values need not be eliminated from consideration as a source of supply, but should be used with caution, and sources of better quality water should be investigated.

### Domestic and Municipal Water Supply

The criteria used in this report for evaluating ground water for domestic use are those included in the California domestic water regulations for chemical and physical quality. Antelope ground water suitability for domestic use was based on an analysis of total dissolved solids, chloride, sulfate, nitrate, and bacteria. Water containing substances exceeding maximum contaminant levels shown in Table 4 may be objectionable, but is not generally hazardous to health. Because historical data indicate some wells produced water containing excessive levels of bacteria and nitrates, area-wide sampling was undertaken to verify the nature and extent of potential problems.

Table 4. Mineralization - Secondary Drinking Water Standards

| Constituent, Units | Maximum Contaminant Levels | | |
|---|---|---|---|
| | Recommended | Upper | Short-Term |
| Total Dissolved Solids, mg/L | 500 | 1,000 | 1,500 |
| or | | | |
| Electrical Conductivity (EC), micromhos/cm | 900 | 1,600 | 2,200 |
| Chloride, mg/L | 250 | 500 | 600 |
| Sulfate, mg/L | 250 | 500 | 600 |

The coliform group of bacteria is relatively easy to isolate and identify in water samples. The standard test of the safety of a water for domestic use is to determine the presence or absence of bacteria by incubating samples in a solution prepared to promote growth. Test results are reported as the most probable number (MPN), an estimate based on probability formulas. The standard to determine potability is an MPN of less than 2.2.

The recommended limit for nitrate in drinking water is 45 mg/L as nitrate (10 mg/L as nitrogen). This limit was included in the 1962 U. S. Drinking Water Standards because of the relationship of high nitrates in drinking water to infant methemoglobinemia (blue baby). The State of California has also adopted this limit in domestic water quality regulations.

### Agricultural Water Supply

Criteria used in this report for agricultural water were developed by the University of California in the early 1970s. Antelope ground water suitability for agricultural use was based on adjusted sodium adsorption ratio (ASAR), TDS, and boron concentration.

ASAR is a useful factor in evaluating the hazard related to changes in soil permeability, root absorption, and the resultant salt buildup caused by high concentrations of sodium in irrigation water. Levels above three can cause increasing problems, and levels greater than nine can cause severe problems.

Ground water with a high concentration of dissolved solids also has limited suitability for agricultural uses. Waters with TDS concentrations of less than 700 mg/L are considered suitable for irrigation. Waters with higher concentrations can be safely used but must be used with care, or problems may develop.

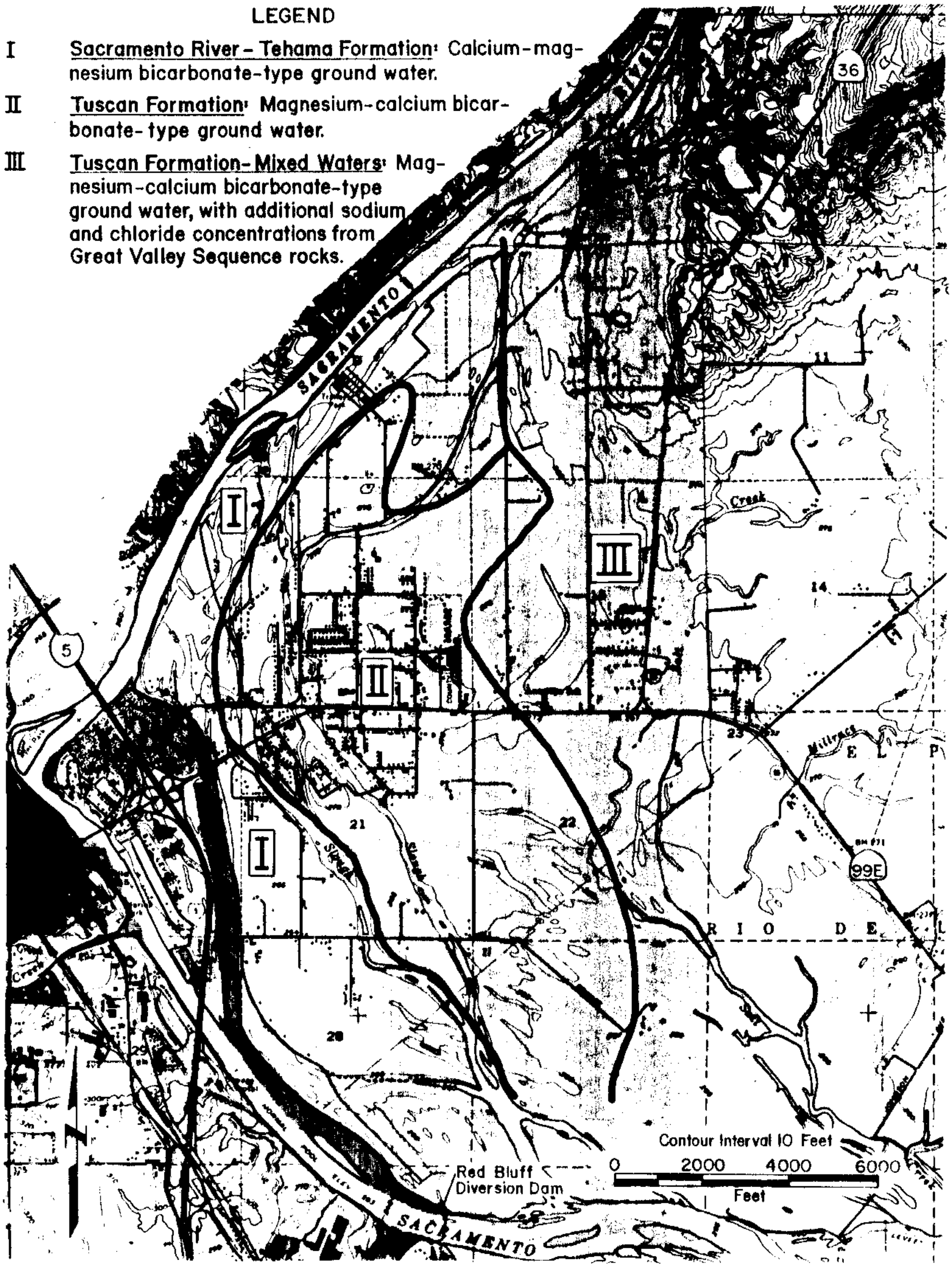
Boron is necessary in small quantities for the normal growth of plants; in larger concentrations, it can be toxic. The recommended limit for boron in irrigation water is 0.5 mg/L.

## Mineral Quality

The Antelope area ground water chemistry (see Figure 19) reflects geologic conditions in the Cascade and Coast Ranges geomorphic provinces, which provide runoff to recharge the Antelope area aquifers. Sacramento River and Tehama Formation aquifers typically contain calcium-magnesium bicarbonate type ground water. Tuscan Formation aquifers usually contain ground water that is magnesium-calcium bicarbonate in character. These waters originate in the Cascade volcanic terrane. In the eastern portion of the study area, sodium chloride waters occur in the Little Salt Creek drainage, probably due to migration of connate water from Great Valley Sequence rocks around Tuscan Springs.

Antelope area ground waters are generally of good mineral quality. Analyses of samples from 75 wells show a TDS range of 140 to 558 mg/L, with a median concentration of 296 mg/L. EC of waters from 72 wells ranged from 205 to 980 μmhos/cm at 25 degrees C, with a median of 450 μmhos/cm. These median

Figure 19




# Antelope Ground Water Study
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values are within the recommended limits and are acceptable for either domestic or irrigation use.

Alkalinity levels expressed as calcium carbonate in Antelope area ground water range from 77 to 253 mg/L with a median concentration of 135 mg/L. Measurements of pH ranged from 6.6 to 8.2, with a median value of 7.1. Alkalinity levels are within the expected range for good quality bicarbonate waters.

All of the well waters tested are bicarbonate in character except one well at the north end of the study area, which is sodium chloride. This well taps confined ground water from the Tuscan Formation that is underlain by Great Valley Sequence rocks. Upward migration of connate water from these rocks is the probable source of sodium chloride.

Elsewhere, the ground water of the Antelope area is a mixture of waters. It is magnesium-calcium bicarbonate in the central portion of the area between Sampson Slough and St. Marys Avenue. West of the slough, the ground water is more calcium rich, matching the calcium-magnesium bicarbonate character of the Sacramento River surface water. Waters in the eastern portion of the area have sodium mixed with calcium or magnesium as the predominate cation. The predominate anion is bicarbonate, with increasing chloride concentrations in the Salt Creek drainage.

Results of the standard mineral analyses for this study are discussed below and then listed in Table 5.

## Sulfates

Sulfate concentrations in the Antelope area are generally low. In 68 wells, the range varied from 2 to 62 mg/L, with a median value of 18 mg/L.

## Hardness

Water from 75 wells in the Antelope area ranged in hardness from 56 to 309 mg/L (expressed as calcium carbonate), with a median of 141 mg/L. Most of these waters are considered soft to moderately hard, but 23 wells produce water with hardness concentrations exceeding 200 mg/L, considered very hard.

## Chlorides

Most chloride levels in the 75 wells tested are low, ranging from 3 to 219 mg/L, with a median value of only 14 mg/L. Only five wells contained concentrations exceeding 100 mg/L.

Chloride concentrations from June 1985 are plotted and contoured in Figure 20. Wells with chloride levels greater than 100 mg/L are in the eastern portion of the area, along Salt Creek. Also, one well at the northern end of the area produces sodium chloride character water. Most wells tested within a mile of the Sacramento River have chloride levels well below 10 mg/L.

Table 5. Analysis of Ground Water

| Date Sampled | State Well Number | Depth of Well | Well Qualification | $NO_3$ | Lab EC | Field pH | Chloride Cl. | Nitrate $No_3$ | Boron B | Adj. SAR | TDS | TH |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6-06-85 | 27N-3W-3H1 | 198 | conf-def | | 680 | 8.0 | 134 | 1.0 | 1.4 | 6 | 418 | 120 |
| 6-26-86 | 27N-3W-3H1 | 198 | conf-def | | 700 | 8.2 | | 0.8 | | | | |
| 6-06-85 | 27N-3W-3N1 | 125 | free-poss | | 279 | 7.8 | 9 | 0.0 | 0.0 | 2 | 209 | 80 |
| 6-26-86 | 27N-3W-3N1 | 125 | free-poss | | 302 | 7.8 | | 0.0 | | | | |
| 6-05-86 | 27N-3W-3P2 | 117 | conf-prob | | 366 | 7.6 | 15 | 0.0 | 0.1 | 2 | 271 | 380 |
| 6-23-86 | 27N-3W-3P2 | 117 | conf-prob | | 390 | 7.5 | | 0.0 | | | | |
| 6-05-85 | 27N-3W-3P3 | 92 | free-poss | | 283 | 8.0 | 12 | 0.1 | | 3 | | 60 |
| 7-01-85 | 27N-3W-3P4 | 85 | conf-def | | 280 | 7.9 | 10 | 0.0 | 0.1 | 3 | 208 | 68 |
| 6-26-86 | 27N-3W-3P4 | 85 | conf-def | | 300 | 8.2 | | 0.0 | | | | |
| 6-04-85 | 27N-3W-9P1 | 152 | free-def | 4 | 283 | 7.1 | 5 | 4.4 | 0.1 | 1 | 201 | 119 |
| 7-23-86 | 27N-3W-9P4 | 90 | | | 464 | 7.0 | 9 | 13 | 0.0 | 1 | 306 | 212 |
| 6-26-86 | 27N-3W-9Q3 | 81 | | | 347 | 7.6 | 4 | 30 | 0.0 | 1 | 263 | 148 |
| 7-23-86 | 27N-3W-9Q4 | 100 | | | 509 | 7.0 | 16 | 50 | 0.0 | 1 | 340 | 246 |
| 6-20-86 | 27N-3W-9Q5 | 83 | | | 521 | 7.5 | 14 | 31 | 0.0 | 1 | 360 | 242 |
| 8-23-85 | 27N-3W-9R2 | 100 | | | 415 | – | 11 | 34 | 0.1 | 1 | 370 | 191 |
| 6-26-86 | 27N-3W-9R2 | 100 | | | 420 | 7.1 | | 33 | | | | |
| 6-04-85 | 27N-3W-10B1 | 92 | comp-prob | | 362 | 7.3 | 14 | 4.4 | 0.1 | 1 | 272 | 126 |
| 6-26-86 | 27N-3W-10B1 | 92 | comp-prob | | 370 | 7.1 | | 4.7 | | | | |
| 6-06-85 | 27N-3W-10B2 | 106 | conf-def | | 274 | 7.4 | 7 | 7.5 | 0.1 | 2 | 230 | 73 |
| 6-06-85 | 27N-3W-10C1 | 110 | conf-def | | 349 | 7.3 | 16 | 3.9 | 0.1 | 2 | 257 | 110 |
| 6-24-86 | 27N-3W-10C1 | 110 | conf-def | | 378 | 7.1 | | 18 | | | | |
| 6-06-85 | 27N-3W-10G1 | 120 | conf-prob | | 415 | 7.6 | 43 | 2.4 | 0.2 | 4 | 290 | 66 |
| 6-23-86 | 27N-3W-10G1 | 120 | conf-prob | | 410 | 7.7 | | 3.2 | | | | |
| 6-06-85 | 27N-3W-10G2 | 100 | comp- | | 355 | 7.3 | 23 | 6.2 | 0.1 | 2 | 258 | 121 |
| 6-26-86 | 27N-3W-10G2 | 100 | comp- | | 400 | 7.3 | | 12 | | | | |
| 7-01-85 | 27N-3W-10G3 | 84 | | | 551 | 7.0 | 26 | 36 | 0.1 | 1 | 386 | 250 |
| 6-26-86 | 27N-3W-10G4 | 148 | | | 383 | 8.0 | 42 | 0.4 | 0.1 | 4 | 265 | 64 |
| 6-24-86 | 27N-3W-10N1 | 307 | | | 372 | 7.1 | 7 | 7.2 | 0.0 | 1 | 259 | 149 |
| 6-04-85 | 27N-3W-10Q1 | 440 | comp-def | | 283 | 8.0 | 11 | 0.3 | 0.1 | 3 | 214 | 62 |
| 6-27-86 | 27N-3W-10Q1 | 440 | comp-def | | 300 | 7.8 | | 0.3 | | | | |
| 7-19-85 | 27N-3W-11L1 | 112 | conf-def | | 454 | 7.2 | 69 | 3.1 | 0.8 | 5 | 296 | 56 |
| 6-27-86 | 27N-3W-11L1 | 112 | conf-def | | 475 | 7.3 | | 3.3 | | | | |
| 7-19-85 | 27N-3W-11P1 | 135 | conf-def | | 616 | 7.2 | 112 | 9.7 | 2.2 | 7 | 379 | 70 |

Table 5. Analysis of Ground Water
(continued)

| Date Sampled | State Well Number | Depth of Well | Well Qualification | $NO_3$ | Lab EC | Field pH | Chloride Cl. | Nitrate $No_3$ | Boron B | Adj. SAR | TDS | TH |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7-19-85 | 27N-3W-11P2 | - | comp-def | | 614 | 7.1 | 93 | 26 | 1.0 | 5 | 383 | 119 |
| 6-27-86 | 27N-3W-11P2 | - | comp-def | | 600 | 7.5 | | 8.3 | | | | |
| 7-19-85 | 27N-3W-14B1 | - | free-def | | 980 | 7.2 | 219 | 2.3 | 3.2 | 9 | 558 | 134 |
| 6-27-86 | 27N-3W-14B1 | - | free-def | | 750 | 7.3 | | 19 | | | | |
| 7-19-85 | 27N-3W-14G1 | - | | | 483 | 7.6 | 36 | 20 | 0.8 | 4 | 310 | 117 |
| 7-19-85 | 27N-3W-14H1 | 96 | semi-conf | | 542 | 7.2 | 91 | 9.3 | 1.4 | 4 | 319 | 114 |
| 6-27-86 | 27N-3W-14H1 | 96 | semi-conf | | 480 | 7.3 | | 20 | | | | |
| 7-22-85 | 27N-3W-14H2 | - | semi-conf | | 494 | 7.0 | 28 | 21 | 0.2 | 2 | 316 | 202 |
| 6-04-85 | 27N-3W-14N1 | 105 | free-prob | | 692 | 6.7 | 98 | 23 | 1.1 | 3 | 430 | 224 |
| 6-23-86 | 27N-3W-14N1 | 105 | free-prob | | 670 | 7.0 | | 23 | | | | |
| 6-04-85 | 27N-3W-15C1 | 140 | | | 569 | 6.9 | 28 | 27 | 0.0 | 1 | 360 | 254 |
| 6-23-86 | 27N-3W-15C1 | 140 | | | 610 | 6.7 | | 38 | | | | |
| 6-04-85 | 27N-3W-15C2 | 264 | | | 306 | 7.3 | 13 | 7.5 | 0.1 | 2 | 229 | 94 |
| 6-23-86 | 27N-3W-15C2 | 264 | | | 320 | 7.5 | | 8.6 | | | | |
| 6-04-85 | 27N-3W-15E1 | 132 | conf | | 617 | 7.0 | 43 | 27 | 0.4 | 1 | 401 | 273 |
| 6-27-86 | 27N-3W-15J2 | 113 | conf-def | | 546 | 7.1 | 90 | 5.8 | 1.2 | 3 | 326 | 153 |
| 6-06-85 | 27N-3W-15K2 | 160 | conf | | 693 | 6.8 | 105 | 5.8 | 1.3 | 4 | 412 | 193 |
| 6-27-86 | 27N-3W-15K2 | 160 | conf | | 750 | 6.6 | | 6.6 | | | | |
| 6-06-85 | 27N-3W-15K3 | 110 | conf-prob | | 602 | 7.1 | 97 | 8.1 | 1.1 | 3 | 382 | 174 |
| 6-27-86 | 27N-3W-15K3 | 110 | conf-prob | | 620 | 7.3 | | 7.6 | | | | |
| 6-05-85 | 27N-3W-15M2 | 120 | | | 647 | 6.8 | 69 | 27 | 0.4 | 2 | 413 | 267 |
| 6-23-86 | 27N-3W-15M2 | 120 | | | 640 | 6.9 | | 30 | | | | |
| 6-06-85 | 27N-3W-15M3 | 68 | conf-prob | | 640 | 7.0 | 99 | 8.8 | 1.1 | 3 | 408 | 193 |
| 6-24-86 | 27N-3W-15M3 | 68 | conf-prob | | 695 | 7.0 | | 13 | | | | |
| 6-04-85 | 27N-3W-15N1 | 124 | conf-prob | | 652 | 7.1 | 60 | 34 | 0.7 | 2 | 427 | 248 |
| 6-23-86 | 27N-3W-15N1 | 124 | conf-prob | | 660 | 7.1 | | 37 | | | | |
| 6-06-85 | 27N-3W-15N2 | 60 | | | 627 | 6.9 | 68 | 16 | 0.6 | 2 | 392 | 231 |
| 6-24-86 | 27N-3W-15N2 | 60 | | | 655 | 6.9 | | 19 | | | | |
| 6-06-85 | 27N-3W-15P1 | 127 | conf-def | | 509 | 7.1 | 58 | 18 | 0.8 | 3 | 317 | 158 |
| 6-24-86 | 27N-3W-15P1 | 127 | conf-def | | 510 | 7.0 | | 24 | | | | |
| 6-20-86 | 27N-3W-16B1 | 132 | | | 384 | 7.3 | 5 | 24 | 0.0 | 1 | 267 | 172 |
| 6-20-86 | 27N-3W-16B2 | 100 | | | 507 | 7.5 | 11 | 16 | 0.0 | 2 | 351 | 223 |
| 7-23-86 | 27N-3W-16C1 | 70 | semi-conf | 32 | 447 | 7.1 | 13 | 32 | 0.0 | 1 | 294 | 202 |

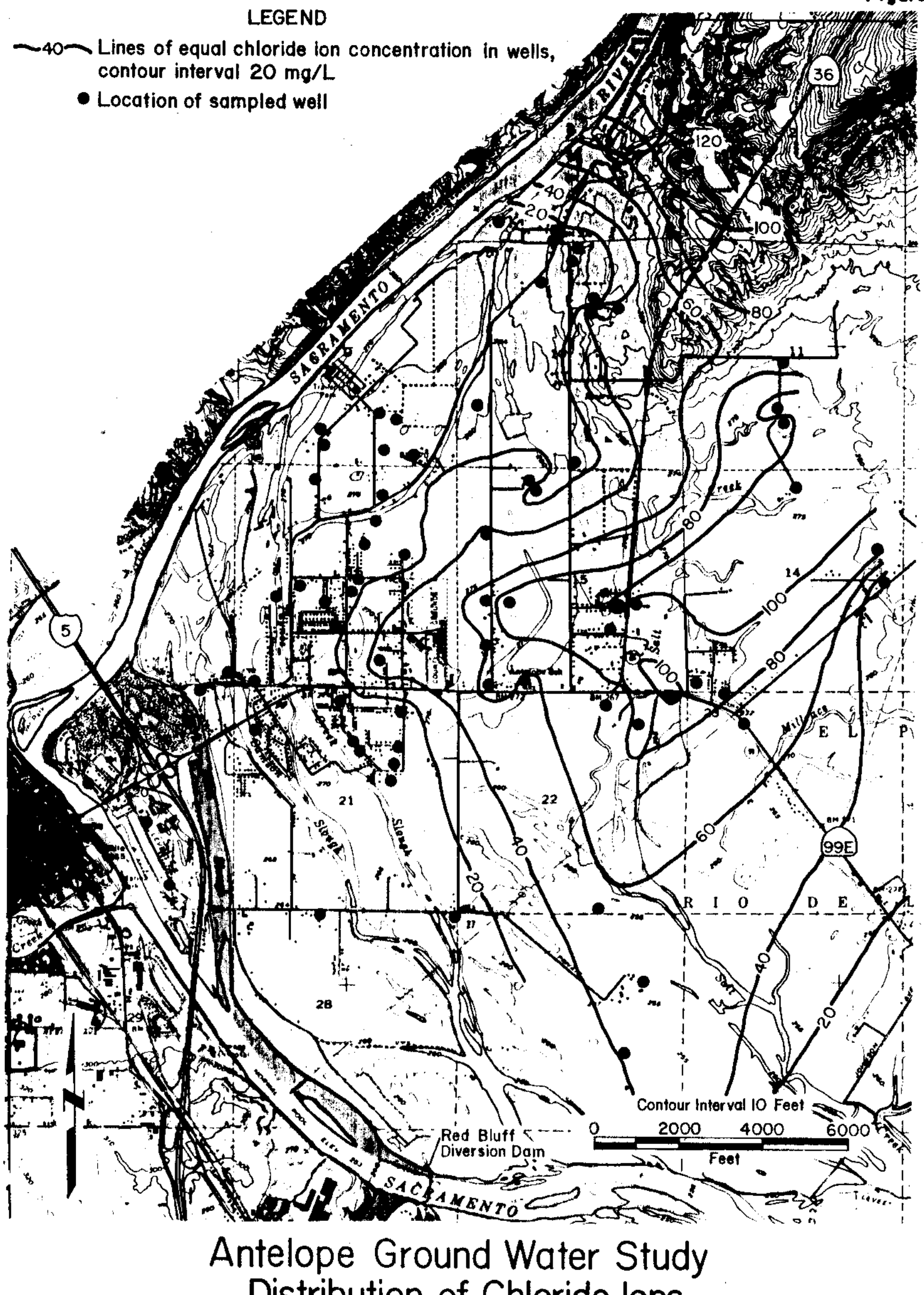
Table 5. Analysis of Ground Water
(continued)

| Date Sampled | State Well Number | Depth of Well | Well Qualification | $NO_3$ | Lab EC | Field pH | Chloride Cl. | Nitrate $No_3$ | Boron B | Adj. SAR | TDS | TH |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6-06-85 | 27N-3W-16G1 | 397 | comp-conf | 8 | 345 | 7.5 | 6 | 8.4 | 0.0 | 1 | 246 | 144 |
| 6-24-86 | 27N-3W-16G1 | 397 | comp-conf | | 385 | 7.3 | | 14 | | | | |
| 3-13-86 | 27N-3W-16G4 | 110 | | | 332 | 7.0 | 7 | 11 | 0.0 | 1 | 232 | 149 |
| 6-23-86 | 27N-3W-16G4 | 110 | | | 502 | 6.9 | 13 | 62 | 0.0 | 1 | 343 | 236 |
| 7-23-86 | 27N-3W-16K1 | 109 | conf-prob | 40 | 577 | 7.1 | 16 | 40 | 0.0 | 1 | 372 | 285 |
| 7-23-86 | 27N-3W-16K2 | 140 | conf-prob | 38 | 622 | 7.1 | 19 | 38 | 0.0 | 1 | 383 | 309 |
| 8-23-85 | 27N-3W-16L1 | 180 | comp/f&c | 38 | 460 | - | 14 | 38 | 0.1 | 1 | 290 | 205 |
| 6-24-86 | 27N-3W-16L1 | 180 | comp/f&c | | 470 | 7.0 | | 46 | | | | |
| 7-23-86 | 27N-3W-16L2 | 110 | | | 432 | 7.1 | 10 | 36 | 0.0 | 1 | 275 | 208 |
| 6-21-86 | 27N-3W-16L3 | 100 | | | 205 | 7.0 | 3 | 10 | 0.0 | 1 | 143 | 81 |
| 6-24-86 | 27N-3W-16M1 | 180 | conf-def | 12 | 236 | 7.5 | 4 | 12 | 0.0 | 1 | 162 | 97 |
| 6-28-85 | 27N-3W-16N2 | 126 | conf | | 283 | 6.9 | 6 | 18 | 0.0 | 1 | 188 | 147 |
| 6-24-86 | 27N-3W-16N2 | 126 | conf | 18 | 282 | 7.0 | | 20 | | | | |
| 6-25-86 | 27N-3W-16Q1 | 80 | semi-conf | 59 | 681 | 6.9 | 50 | 59 | 0.3 | 2 | 424 | 308 |
| 10-16-85 | 27N-3W-17R2 | 90 | | | 207 | 7.1 | 3 | 9.7 | 0.0 | 1 | 140 | 81 |
| 6-24-86 | 27N-3W-17R2 | 90 | | | 215 | 7.1 | | 14 | | | | |
| 6-04-85 | 27N-3W-20A1 | 625 | comp/c-def | | 261 | 7.5 | 4 | 4.6 | - | 1 | - | 96 |
| 6-25-86 | 27N-3W-20A1 | 625 | comp/c-def | | 242 | 7.5 | | 6.4 | | | | |
| 9-13-85 | 27N-3W-20F1 | 272 | | | 234 | 7.6 | 3 | 5.2 | 0.0 | 1 | 166 | 92 |
| 6-25-86 | 27N-3W-20F1 | 272 | | | 223 | 7.8 | | 3.8 | | | | |
| 9-13-85 | 27N-3W-20K1 | 182 | comp/f&c-def | | 300 | 6.8 | 6 | 13 | 0.0 | 1 | 191 | 126 |
| 9-13-85 | 27N-3W-20Q4 | 75 | free-def | | 306 | 7.0 | 7 | 2.0 | 0.0 | 1 | 186 | 130 |
| 6-25-86 | 27N-3W-20Q4 | 75 | free-def | | 335 | 7.0 | | 7.3 | | | | |
| 7-23-86 | 27N-3W-21B1 | 92 | semi-conf | 25 | 378 | 7.0 | 10 | 25 | 0.2 | 1 | 244 | 157 |
| 6-04-85 | 27N-3W-21C1 | 320 | conf | | 294 | 7.3 | 6 | 16 | 0.1 | 1 | 204 | 118 |
| 6-24-86 | 27N-3W-21C1 | 320 | conf | 16 | 315 | 7.3 | | 19 | | | | |
| 7-23-86 | 27N-3W-21D1 | 109 | conf-prob | 7 | 209 | 7.3 | 4 | 7.2 | 0.0 | 1 | 141 | 90 |
| 10-16-85 | 27N-3W-21G1 | 152 | conf-prob | | 296 | 7.4 | 6 | 13 | 0.0 | 1 | 190 | 119 |
| 6-25-86 | 27N-3W-21G1 | 152 | conf-prob | 13 | 300 | 7.8 | | 19 | | | | |
| 7-23-86 | 27N-3W-21G2 | 80 | conf-prob | 25 | 476 | 6.9 | 13 | 25 | 0.1 | 1 | 320 | 220 |
| 7-23-86 | 27N-3W-21G3 | 79 | | | 309 | 7.0 | 7 | 16 | 0.1 | 1 | 309 | 135 |
| 7-23-86 | 27N-3W-21G4 | 80 | | | 369 | 6.9 | 9 | 18 | 0.1 | 1 | 244 | 168 |
| 7-23-86 | 27N-3W-21G5 | 81 | semi-conf | 25 | 450 | 7.0 | 11 | 25 | 0.1 | 1 | 304 | 205 |

Table 5. Analysis of Ground Water
(continued)

| Date Sampled | State Well Number | Depth of Well | Well Qualification | $NO_3$ | Lab EC | Field pH | Chloride Cl. | Nitrate $No_3$ | Boron B | Adj. SAR | TDS | TH |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6-25-85 | 27N-3W-22A1 | 248 | conf-def | | 602 | 7.1 | 103 | 8.8 | 1.3 | 5 | 355 | 116 |
| 6-20-86 | 27N-3W-22A1 | 248 | conf-def | | 605 | 7.0 | | 8.5 | | | | |
| 7-15-85 | 27N-3W-22B1 | 220 | comp/ f&c-def | | 576 | 7.1 | 81 | 13 | 1.6 | 5 | 347 | 119 |
| 6-21-85 | 27N-3W-22B3 | 170 | comp/ f&c-poss | | 539 | 7.3 | 71 | 13 | 1.1 | 4 | 327 | 141 |
| 6-20-86 | 27N-3W-22B3 | 170 | comp/ f&c-poss | | 520 | 7.1 | | 13 | | | | |
| 6-21-85 | 27N-3W-22Q1 | - | | | 506 | 7.0 | 61 | 18 | 0.9 | 3 | 312 | 143 |
| 6-20-86 | 27N-3W-22Q1 | - | | | 460 | 7.1 | 55 | 13 | 0.9 | 3 | 278 | 129 |
| 6-04-85 | 27N-3W-23D1 | 158 | | | 573 | 7.0 | 71 | 18 | - | 4 | 573 | 142 |
| 6-21-85 | 27N-3W-27H1 | - | | | 578 | 6.8 | 53 | 17 | 0.7 | 2 | 362 | 210 |
| 6-26-85 | 27N-3W-27K1 | 216 | comp/ f&c-def | | 435 | 7.1 | 41 | 11 | 0.9 | 4 | 268 | 108 |
| 7-15-85 | 27N-3W-27R1 | 104 | | | 549 | 7.1 | 58 | 26 | 0.8 | 3 | 339 | 157 |
| 6-28-85 | 27N-3W-28A2 | - | | | 331 | 7.1 | 6 | 12 | 0.2 | 1 | 219 | 142 |
| 6-21-85 | 27N-3W-28C3 | 70 | free-prob | | 227 | 7.1 | 4 | 6.5 | - | 1 | - | 115 |
| 6-25-86 | 27N-3W-28C3 | 70 | | | 218 | 7.0 | | 5.0 | | | | |

Figure 20




Antelope Ground Water Study
Distribution of Chloride Ions

### Nitrates

Drinking water has a recommended limit of 45 mg/L nitrate. Four of the 72 wells tested in 1986 exceeded that limit. In general, nitrate levels are moderate in the Antelope area, ranging from 0 to 62 mg/L, with a median value of 14 mg/L.

Figure 21 shows the pattern of nitrate occurrence found in the area during 1986 sampling. Water containing the higher concentrations of nitrates came from wells in an area north of Antelope Boulevard adjacent to Chestnut and Mulberry Avenues.

### Phosphates

Total phosphorous as P was analyzed in 54 wells. Values ranged from 0.02 to 0.22 mg/L, with a median of 0.06 mg/L. Although no distinct pattern of distribution was discernible, the highest concentrations of phosphorus were found in the Salt Creek drainage and in an area at the north edge of the study area associated with water from the Tuscan Formation.

### Sodium Adsorption Ratio

Adjusted Sodium Adsorption Ratio (ASAR) values for 71 wells range from 0.5 to 8.8, and have a median of 1.6. None of the water had an ASAR value exceeding 9, although two had values exceeding 6 and seventeen wells had values exceeding 3. All 17 wells producing water with the high ASAR values are along Salt Creek, in the eastern portion of the study area.

### Boron

Boron concentrations in 67 wells ranged from 0 to 2.2 mg/L, with a median concentration of 0.1 mg/L. Eleven wells produce water containing boron in excess of 1 mg/L; these are in the vicinity of Salt Creek, which flows along the eastern edge of the study area. Two wells in the Salt Creek drainage had boron levels greater than 2 mg/L.

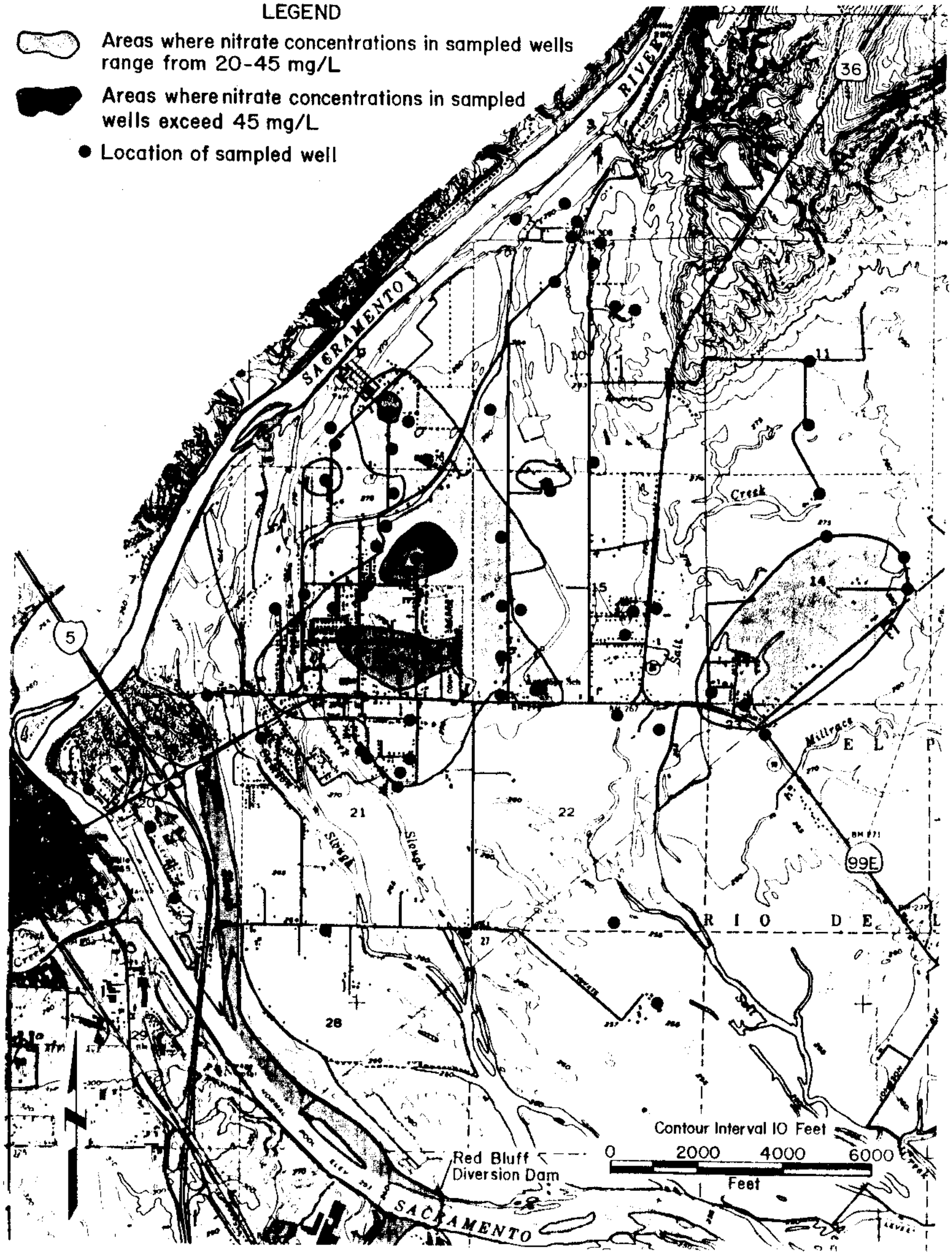
## Bacteriological Quality

Numerous historic bacteriological samples taken from domestic water supply systems had shown the widespread presence of coliform bacteria throughout the study area. An area-wide sampling of 20 wells was made to determine if bacterial contamination of the ground water had occurred. The bacteriological samples were taken by Tehama County personnel either directly from the well or from the nearest point from which the water could be sampled in the water system. The samples were tested for both total and fecal coliform, with the following results:

18 samples = <2.2 MPN
1 sample = 16 total and <2.2 fecal MPN
1 sample = 16 total and 16 fecal MPN

Health departments usually consider <2.2 MPN as uncontaminated, while 16 MPN is considered excessively contaminated.

Figure 21




Antelope Ground Water Study
Distribution of Nitrate

The two samples in which coliform bacteria were found were from water systems near the end of St. Mary's Avenue. As wells in the same general area showed no contamination, these two probably represent system or local contamination.

## Water Quality Problems

Ground water in the Antelope area is generally good, but localized problems are limiting its beneficial uses. Most of the poorer quality waters are from two areas: one in the west-central portion of the study area where high nitrate levels are found, and one in the eastern portion of the study area where high boron and salt contents are found. Six wells in Antelope have produced water containing mineral constituents in excess of recommended levels for drinking water. Four exceeded the maximum recommended level of 45 mg/L for nitrate, while two wells exceeded 500 mg/L for TDS, which is the recommended limit. Eighteen wells yield water having ASAR values exceeding 3, which indicates their use for irrigation could cause some problems. Two wells with high ASAR values also contain boron concentrations exceeding 2 mg/L, which indicates they can damage most crops.

Historical data and information indicate that three ground water quality problems may exist in the Antelope area: nitrate contamination, bacterial contamination, and excessive levels of boron. The nature and extent of each of these problems is discussed in the following sections.

### Nitrate Problem

Historical water quality data indicate that a few wells in the Antelope area were producing water containing nitrate concentrations exceeding the maximum value (45 mg/L) recommended in the drinking water standards. During this study, 4 of 78 wells sampled produced water containing nitrate concentrations exceeding 45 mg/L; 16 wells produced water with concentrations of nitrate exceeding 30 mg/L.

Nitrate Toxicity. Due to the relationship between high nitrates in drinking water and infant methemoglobinemia, a recommended limit of 45 mg/L as nitrate (10 mg/L as nitrogen) was included in the 1962 U. S. Drinking Water Standards. The State of California also recommends this limit for domestic water.

Although nitrates have been shown to be toxic to both humans and animals, they are generally much less toxic to animals. Nitrate toxicity in humans is generally limited to children less than three months old and effects can range from mild illness to death. Cases of nitrate poisoning in adults are rare.

The following information on nitrate toxicity was extracted from the Environmental Protection Agency's 1976 report, "Quality Criteria for Water".

In quantities normally found in food or feed, nitrates become toxic only under conditions in which they are, or may be, reduced to nitrites.

Otherwise, at "reasonable" concentrations, nitrates are rapidly excreted in the urine. High intake of nitrates constitutes a hazard primarily to warm-blooded animals under conditions that are favorable to their reduction to nitrite. Under certain circumstances, nitrate can be reduced in the gastrointestinal tract to nitrite, which then reaches the bloodstream and reacts directly with hemoglobin to produce methemoglobin, with consequent impairment of oxygen transport.

The reaction of nitrite with hemoglobin can be hazardous in infants under three months of age. Serious and occasionally fatal poisonings in infants have occurred following ingestion of untreated well waters shown to contain nitrate at concentrations greater than 45 mg/L. High nitrate concentrations frequently are found in shallow farm and rural community wells, often as the result of inadequate protection from barnyard drainage or from septic tanks. Approximately 2,000 cases of infant methemoglobinemia have been reported in Europe and North America since 1945; 7 to 8 percent of the affected infants died. Many infants have drunk water in which the nitrate content was greater than 45 mg/L without developing methemoglobinemia. Many public water supplies in the United States contain levels that routinely are in excess of this amount, but only one case* of infant methemoglobinemia associated with a public water supply has been reported in the United States. The differences in susceptibility to methemoglobinemia are not yet understood, but appear to be related to a combination of factors including nitrate concentrations, enteric bacteria, and the lower acidity characteristic of the digestive systems of baby mammals. Methemoglobinemia symptoms and other toxic effects were observed when high nitrate well waters containing pathogenic bacteria were fed to laboratory mammals. Conventional water treatment has no significant effect on nitrate removal from water.

Because of the potential risk of methemoglobinemia to bottle-fed infants, and in view of the absence of substantiated physiological effects at nitrate concentrations below 45 mg/L, this level is the criterion for domestic water supplies.

Nitrate Sources. There are numerous sources of nitrogen within the study area that can contribute to nitrates in the ground water. The largest sources are probably domestic wastes, decomposing organic matter, fertilizers, and fixation of atmospheric nitrogen (see Figure 22). Also, processes within the unsaturated zone are intercepting and keeping nitrogen compounds out of the ground water. The more important of these are uptake by plants in the root zone, ammonia volatilization, and microbial reduction of nitrate and denitrification.

Only a small area in the western portion of the Antelope area is sewered. In the rest of the study area, domestic wastes are usually treated in septic tanks and discharged through subsurface leach fields. The area now sewered was occupied prior to the sewering, and individual disposal systems probably have added and may still be adding nutrients to the shallow ground water.

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* Several infant deaths have been reported since 1976.

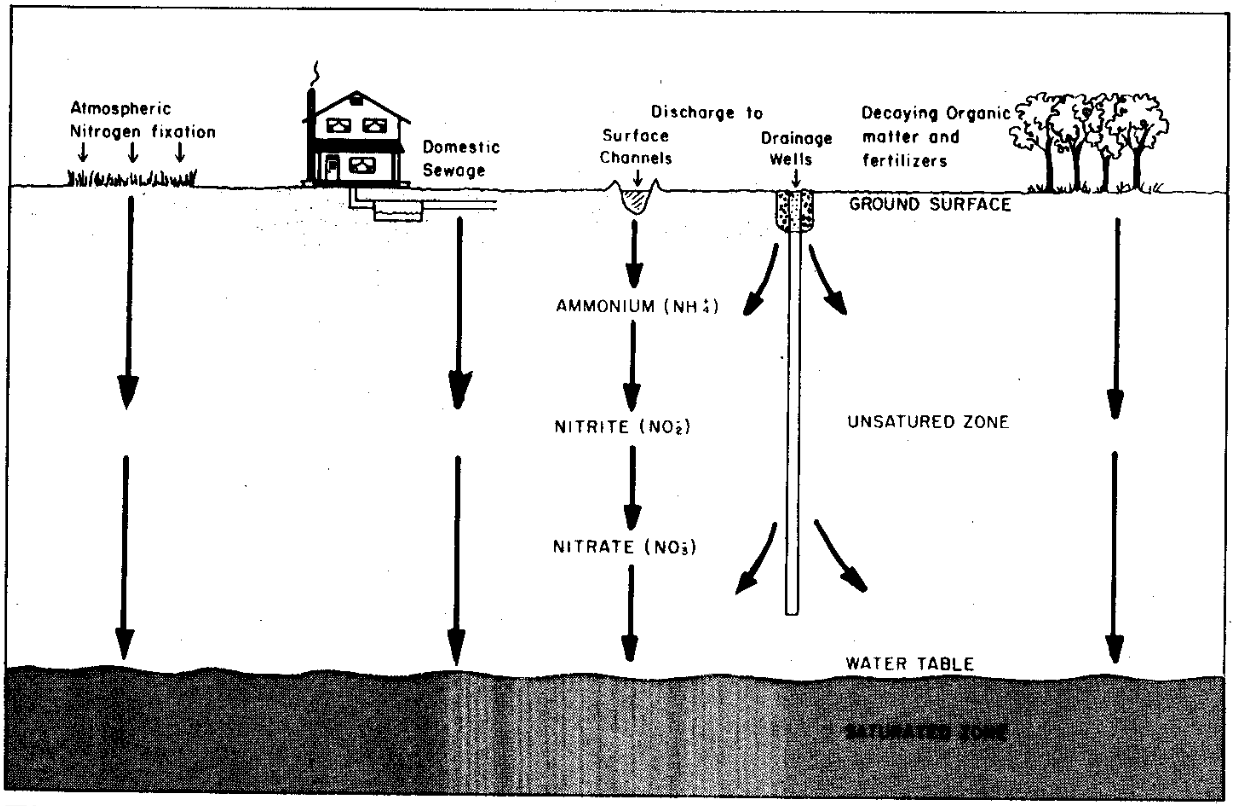


**Figure 22 Nitrate sources to ground water.**

The amount of mineralization of water resulting from its use for domestic purposes varies somewhat with area and mineral content of the water supply. However, studies indicate that the total nitrogen content can increase by 20 to 40 mg/L after being used for domestic purposes. If the nitrogenous compounds are converted to nitrate, the undiluted leachate from this source could contain two to four times the acceptable level for drinking water. However, some nitrogen is usually removed in septic tanks and in the leachfield areas by plant uptake, denitrification, and ammonia volatilization.

Throughout much of the Antelope area, the shallow ground water table is often less than 30 feet below ground surface, limiting the extent of the unsaturated zone and the nitrogen removal processes. Paving and buildings have covered some areas, reducing direct ground water recharge by rain. Rain contains few dissolved solids and low concentrations of nitrogenous compounds, so this reduction in recharge results in less dilution of domestic waste effluents.

The point source nature of domestic waste disposal and variations in ground water recharge combine to form receiving waters that vary considerably in quality.

In most areas naturally occurring organic materials, such as leaves, wood fiber, and bark, accumulate and decompose. During decomposition, most nutrients are recycled within the soil vegetation system, but some are carried downward to the water table by percolating water. Organics associated with human habitation, such as lawn clippings, bush and tree trimmings, and waste paper, are often added to the natural accumulations, resulting in greater release and escape of nitrates to ground water.

Surface runoff from commercial and residential areas concentrates some of the organics and transports them into adjacent drainage channels. From these channels, percolating water carries soluble organics and some decomposition products down to the water table.

Most of the fertilizers used on agricultural crops, lawns, and gardens contain nitrogen. The four forms of nitrogen most commonly applied are: nitrate ($NO_3$), ammonia ($NH_3$) ammonia ($NH_4$), and urea ($[NH_2]_2CO$). Some of the nitrogen in these fertilizers is converted to nitrate and carried below the root zone by downward moving irrigation water or precipitation. The form of fertilizer, type of crop, nature of soil, and irrigation practices influence the loss of nitrates to ground water.

The recommended annual application rates for nitrogen in orchards vary greatly; in the Antelope area, recommended rates are 60 to 100 pounds per acre for almonds and 100 to 125 pounds per acre for walnuts. Most field crops, except alfalfa and pasture, have application rates that fall within these ranges. However, there is probably more variability between individual grower's application practices than between recommended applications.

Most agricultural land in the Antelope area has loam or sandy loam soil, which has medium to high percolation rates that make them conducive to loss of nutrients to ground water.

Nitrogen fixation is the binding of atmospheric nitrogen into nitrogenous compounds by bacterial action. There are numerous free-living bacteria in nearly all soils that fix nitrogen. These bacteria can fix up to 300 pounds of nitrogen per acre annually, but generally fix only about 6 pounds per acre. Symbiotic nitrogen fixation, however, by Rhizobium micro-organisms in association with leguminous plants, usually results in the fixation of several hundred pounds per acre and is a well known source of nitrates. Alfalfa fields and pasture containing legumes such as clover, alfalfa, and vetch are not prevalent in the Antelope area, but there are several small plots. While they are probably not a major source of nitrates, they may have added significantly to localized nitrate concentrations.

Occurrence in the Study Area. The distribution of nitrate concentrations in the Antelope area ground water is shown on Figure 21. Well waters containing the highest concentrations of nitrates are in the west-central portion of the study area, north and west of State Highway 36.

As described in the hydrology section, the ground water in this area is recharged from direct precipitation and from the Sacramento River. The ground water moves from the Sacramento River in a southeasterly direction through this area. Sacramento River water is of excellent mineral quality, low in dissolved solids and chlorides, and seldom contains nitrates. As the ground water moves through the basin, mineral content increases.

Wells with the highest concentrations of nitrates are all in developed residential areas or adjacent to domestic waste water disposal systems that serve a number of people. Past agricultural contributions and current fertilizer applications in up-gradient areas may have also contributed nitrates.

The area of highest nitrate is underlain by a layer of fine-grained sediments described in the geologic and hydrologic sections. This layer permits recycling of ground water extracted from wells and returned through percolation from sewage disposal systems or irrigated areas with a minimum amount of dilution by water from other sources.

Well water in the area of higher nitrates also shows increased levels of EC, chloride, and hardness, which are typically caused by organic wastes and recycling. Phosphorus levels were not high in this area, but this would be expected, as phosphorus uptake and stripping in many fine-grained productive soils are very efficient within the root zone, limiting buildup.

## Bacteria Problem

Numerous bacteriological tests on samples from ground water systems in the Antelope area in the past have indicated contamination. Because most samples were collected from taps inside the houses, they could indicate system contamination rather than ground water contamination. Samples collected during this study were collected from taps at or as near as possible to the well.

Twenty wells throughout the Antelope area were sampled in June 1986. June sampling provides data following the spring recharge period, when contamination is most likely. The results indicate that there is no widespread bacterial contamination in the study area. Only two samples gave positive results, and these could have been the result of local or system contamination rather than ground water contamination.

However, the two wells are from the same general area and draw water from the Tuscan Formation. Because this formation contains fractures in this area that could serve as conduits for local water movement, the possibility of ground water contamination exists at either location.

Few wells were available to sample the very shallow ground water throughout the area, so some bacterial contamination may be occurring there, particularly in the residential area where density of waste disposal systems is high and nitrate levels are elevated. The more detailed study being conducted by CMA for the County should provide information on any contamination of these shallow waters.

## Boron Problem

High concentrations of boron are found in the ground water along the eastern portion of the study area underlying Salt and Little Salt Creeks (see Figure 23). The ground water in this area also frequently contains higher concentrations of chloride and total dissolved solids than does other water in the study area. It also has higher adjusted sodium adsorption ratios, which indicate potential problems with irrigation use.

The boron and other dissolved solids that have impaired the ground water in this area probably come from the Great Valley Sequence rocks, which are exposed higher in the watershed and in the water that flows from Tuscan and Salt Creek Springs. The spring water contains boron in concentrations as high as 200 mg/L, and has electrical conductivities in excess of 28,000 μmho/cm.

Farmers have been aware of this poor quality water for many years, and they have avoided boron- and salt-sensitive crops and have used care in irrigation practices. Boron and salt concentrations are not expected to reduce much in the near future, and the affected area is expected to remain the same.

Figure 23


Antelope Ground Water Study
Distribution of Boron

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## GLOSSARY OF TERMS

The terms listed in this Glossary of Terms are referenced from the American Geological Institute's (AGI) "Glossary of Geology" (1977 and 1983, second edition) and DWR's Bulletin 118-1, Volume IV.

Agglomerate - A chaotic assemblage of coarse, angular pyroclastic materials; Cf: volcanic breccia.

Alluvium - A general term for clay, silt, sand and gravel, or similar unconsolidated detrital material deposited during comparatively recent geologic time by a stream or other body of running water as a sorted or semisorted sediment.

Anticline - A fold, generally convex upward, whose core contains the stratigraphically older rocks.

Aquiclude - A body of relatively impermeable rock that is capable of absorbing water slowly but does not transmit it rapidly enough to supply a well or a spring.

Aquifer - A body of rock that is sufficiently permeable to conduct ground water and to yield economically significant quantities of water to wells and springs.

Artesian Aquifer - Confined aquifer.

Artesian Well - A well tapping confined ground water. Water in the well rises above the level of the water table under artesian pressure, but does not necessarily reach the land surface.

Breccia - A coarse-grained clastic rock, composed of angular broken rock fragments held together by a mineral cement or in a fine-grained mixture.

Confined Ground Water - Ground water under pressure significantly greater than that of the atmosphere. Its upper surface is the bottom of an impermeable bed or a bed of distinctly lower permeability than the material in which the water occurs.

Connate Water - Water entrapped in the intertices of a sedimentary rock at the time of its deposition.

Discharge Area - An area in which subsurface water, including both ground water and vadose water is discharged to the land surface, to bodies of water, or to the atmosphere.

Electrical Conductivity - A measure of the ease with which a conduction current will flow through a material under the influence of an applied electric field. It is the reciprocal of resistivity and is measured in mhos per meter.

Fanglomerate - A sedimentary rock consisting of slightly water-worn, heterogeneous fragments of all sizes, deposited in an alluvial fan and later cemented into a firm rock. The term was proposed by Lawson (1913, p. 329) for the coarser, consolidated rock material occurring in the upper part of an alluvial fan.

Fluvial Deposit - A sedimentary deposit consisting of material transported by, suspended in, or laid down by a stream.

Impermeability - The condition of a rock sediment or soil that renders it incapable of transmitting fluids under pressure.

Lapilli - Pyroclastics that may be either essential, accessory, or accidental in origin, of a size range that has been variously defined within the limits of 2 and 64 mm.

Monocline - A local steepening in an otherwise uniform gentle dip.

Pedogenic - Pertaining to soil formation.

Perched Ground Water - Unconfined ground water separated from an underlying main body of ground water by an unsaturated zone.

Percolation - Slow laminar movement of water through small openings within a porous material. Also used as a synonym of "infiltration".

Permeability - The property or capacity of a porous rock, sediment, or soil for transmitting a fluid; it is a measure of the relative ease of fluid flow under unequal pressure.

Piezometric Surface - Potentiometric surface.

Pore - A small to minute opening or passageway in a rock or soil; an interstice.

Porosity - The percentage of the bulk volume of a rock or soil that is occupied by interstices, whether isolated or connected.

Potentiometric Surface - An imaginary surface representing the total head of ground water and defined by the level to which water will rise in a well. The water table is a particular potentiometric surface.

Pyroclastic - Pertaining to clastic rock material formed by volcanic explosion or aerial expulsion from a volcanic vent.

Recharge Area - An area in which water is absorbed that eventually reaches the zone of saturation in one or more aquifers.

Semiconfined Ground Water - A condition of an aquifer, or group of aquifers, in which ground water movement is sufficiently restricted to cause slight differences in head between differing depth zones during periods of heavy pumping and no head differences during periods of little draft (Bulletin 118-1, Volume IV).

Specific Capacity - The rate of discharge of a water well per unit of drawdown, commonly expressed in gallons per minute per foot.

Specific Yield - The ratio of the volume of water that a given mass of saturated rock or soil will yield by gravity to the volume of that mass. This ratio is stated as a percentage.

Syncline - A fold, generally concave upward, whose core contains the stratigraphically younger rocks.

Thermal Water - Water, generally of a spring or geyser, whose temperature is appreciably above the local mean annual air temperature.

Tuff - A compacted pyroclastic deposit of volcanic ash and dust that may not contain up to 50 percent sediments such as sand or clay (Glossary of Geology, 1977).

Tuff Breccia - A pyroclastic rock consisting of more or less equal amounts of ash, lapilli, and larger fragments.

Unconfined (Free) Ground Water - Ground water that has a free water table--i.e., water not confined under pressure beneath relatively impermeable rocks.

Water Table - The surface between the zone of saturation and the zone of aeration; that surface of a body of unconfined ground water at which the pressure is equal to that of the atmosphere.

Zone of Aeration - A subsurface zone containing water under pressure less than that of the atmosphere, including water held by capillarity, and containing air or gases generally under atmospheric pressure. This zone is limited above by the land surface and below by the surface of the zone of saturation--i.e., the water table.

Zone of Saturation - A subsurface zone in which all the interstices are filled with water under pressure greater than that of the atmosphere. Although the zone may contain gas-filled interstices or interstices filled with fluids other than water, it is still considered saturated. This zone is separated from the zone of aeration (above) by the water table.